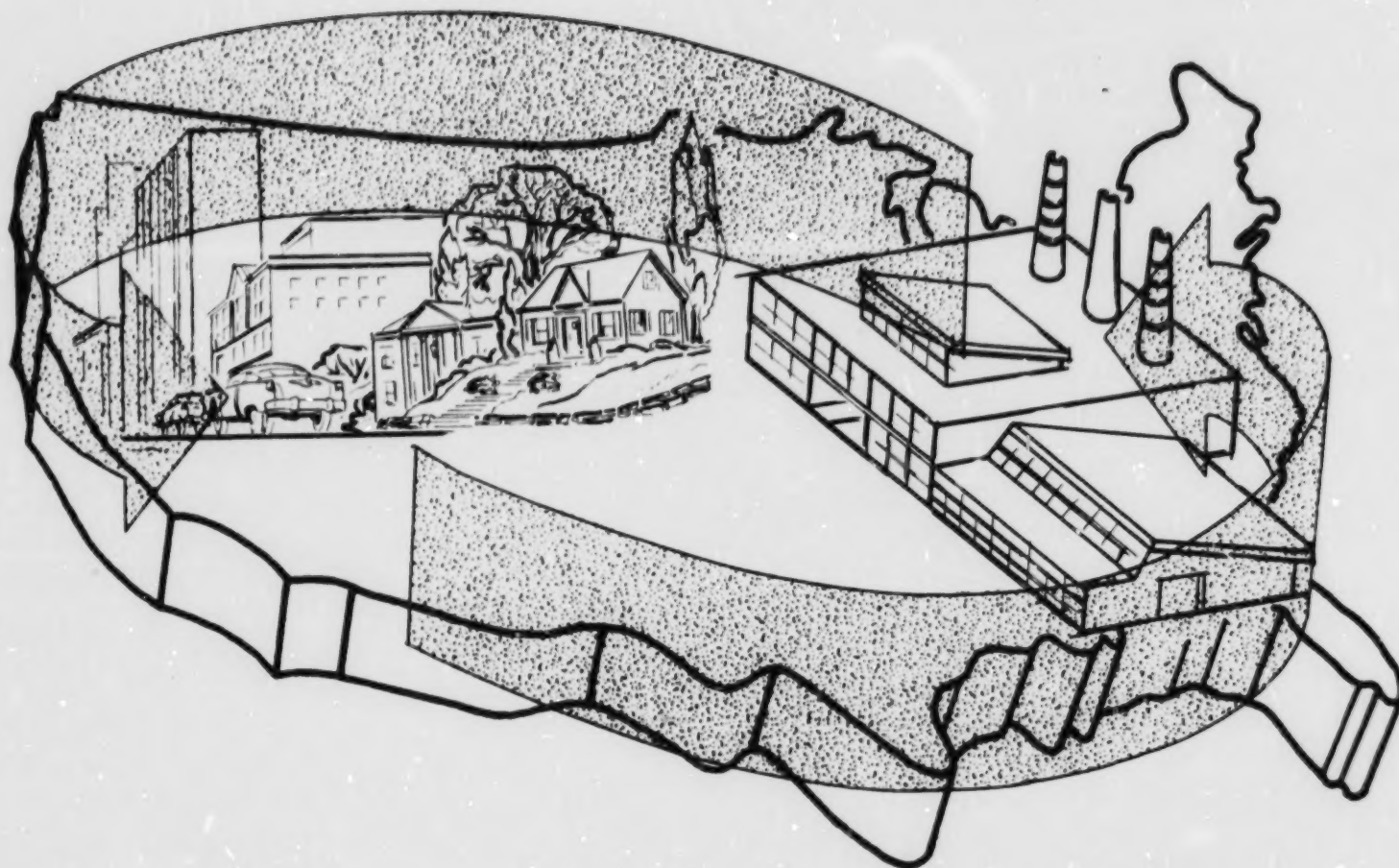


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**IRONTON, OHIO - ASHLAND, KENTUCKY -
HUNTINGTON, WEST VIRGINIA**

AIR POLLUTION ABATEMENT ACTIVITY

PRE-CONFERENCE INVESTIGATIONS



U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

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TECHNICAL REPORT

**IRONTON, OHIO - ASHLAND, KENTUCKY -
HUNTINGTON, WEST VIRGINIA**

AIR POLLUTION ABATEMENT ACTIVITY

PRE-CONFERENCE INVESTIGATIONS

Prepared for Conference Use Only

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Bureau of Disease Prevention and Environmental Control
National Center for Air Pollution Control

Cincinnati, Ohio
May 1968

This report is based upon an investigation of air pollution conducted in the Ironton, Ohio; Ashland, Kentucky; and Huntington, West Virginia areas for the period of September 1965 to August 1967. The report is intended to assist the governmental agencies concerned with such air pollution in their consideration of the following:

1. Occurrence of air pollution subject to abatement.
2. Adequacy of measures taken toward abatement of pollution.
3. Nature of delay, if any, in abating the pollution.
4. Necessary remedial action, if any.

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**IRONTON, OHIO - ASHLAND, KENTUCKY -
HUNTINGTON, WEST VIRGINIA**

AIR POLLUTION ABATEMENT ACTIVITY

I. INTRODUCTION

Air pollution has been the subject of long-standing complaints in the area of the Ohio River Valley where Ohio, Kentucky, and West Virginia adjoin. The degradation of air quality by smoke and dust emissions from industrial plants has been of concern to many area residents and in particular to citizens of Ironton, Ohio.

In 1964, at the urging of an organized citizens' group, city and county officials in Ironton requested assistance from the Ohio Department of Health and the Division of Air Pollution, Public Health Service, in determining the extent of air pollution in Ironton, Ohio, and in implementing a local control program.

In response, the Ohio Department of Health conducted an air pollution survey in Ironton during the spring and summer of 1964. Measurements obtained during the survey clearly showed excessive levels of air pollution in the community. Representatives of the Ohio Department of Health and the Public Health Service met with Ironton and Lawrence County officials to discuss the survey findings and provide guidance in resolving the air pollution problem.

Many of the pollution sources affecting the Ironton area were found to be located outside of the jurisdiction of the city, and air pollution ordinances and control authority enacted by the City of Ironton would be of limited effectiveness because of sources in the county as well as the interstate nature of the problem.

HISTORY OF ABATEMENT INVESTIGATION

Subsection 105 (c) (1) (C) of the Clean Air Act, as amended (42 U.S.C. 1857, et seq.), placed upon the Secretary of Health, Education, and Welfare the responsibility to initiate air pollution abatement action when he has reason to believe that pollution generated in one state endangers the health or welfare of any persons in another state.

Available information on the geographic distribution of sources and meteorology of the area indicated potential interstate transport of air pollutants of sufficient magnitude to endanger health and welfare. In September 1965, as part of the national surveillance program, the Abatement Program, National Center for Air Pollution Control, initiated intelligence-gathering activities aimed at obtaining information relative to existing and potential air quality within the area encompassing Ironton, Ohio; Ashland, Kentucky; and Huntington, West Virginia. Technical direction, administration, and coordination of the survey were provided by the Abatement Program, with full cooperation of the state and local officials.

On the basis of preliminary data generated by the self-initiated survey, the Secretary of Health, Education, and Welfare requested officials of Kentucky, Ohio, and West Virginia to consult with the Department of Health, Education, and Welfare on air pollution in the interstate area. On August 25, 1966, representatives of the three state agencies, local governmental agencies invited by the states, and the Public Health Service met for consultation in Ironton, Ohio. The conduct of the investigation, the specific interests of the various agencies, and the prospects for further activity were discussed at the meeting.

An air sampling program by the Abatement Program was completed in the autumn of 1966, and field activities for an emissions inventory were accomplished during the summer of 1967.

DESCRIPTION OF STUDY AREA

The geographic area of the study consists of the five-county, tri-state area shown in Figure 1. The study boundaries include Greenup and Boyd Counties in Kentucky, Lawrence County in Ohio, and Wayne and Cabell Counties in West Virginia. The principal municipalities of the area are Ashland, Kentucky; Ironton, Ohio; and Huntington, West Virginia. The area of primary interest in the study is that encompassed generally by a circle of 10-mile radius about the intersection of the state lines of Kentucky, Ohio, and West Virginia.

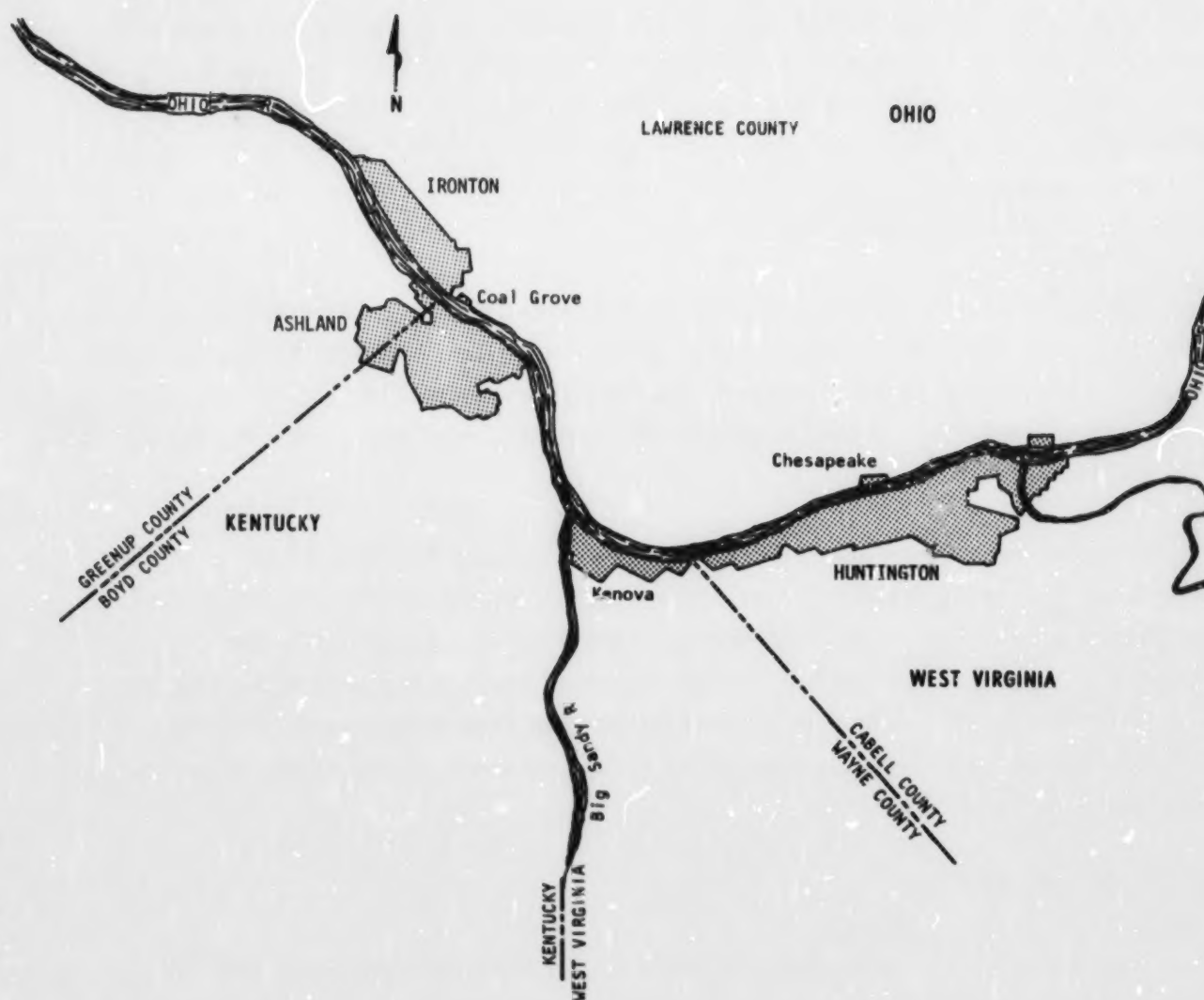


Figure 1. Geographical location of study area.

According to 1964 estimates, more than 250,000 people reside within the 1500-square-mile study area. About 52 percent of the area population live in the West Virginia portion; 28 percent in Kentucky; and 20 percent in Ohio. Huntington, West Virginia, with a population of 76,200, is the major wholesale and retail center for the metropolitan area. Ashland, Kentucky, with a population of 31,000, and Ironton, Ohio, with a population of 15,500, serve as trade centers for surrounding counties in Kentucky and Ohio.

The area's long history of industrial activity reaches back to the mid-1800's. At the present time manufacturing provides the major source of employment. Typical of industrialized regions of the Ohio River Valley, parts of the Ironton-Ashland-Huntington area are dominated by heavy industry, notably the metallurgical and chemical industries.

Coal is transported by rail to the area where it is converted to coke for the production of iron and steel. Metallurgical facilities in the area include coking operations, open-hearth furnaces, blast furnaces, foundries, rolling mills, and galvanizing plants. Also included in the metallurgical group are plants involved in nickel, copper, and brass processing. Most of these industries have been in operation since before World War II.

The chemical industries, like the metallurgical group, were established in the area over a long period of time. Their production volume and the variety of their products have continued to increase. Chemical products include liquid fertilizers, formaldehyde, melamine, phthalic anhydride, creosote, road tars, ammonia, activated carbon, and petrochemicals.

A significant departure from the industrial pattern in other sections of the Ohio River Valley is the absence of steam-electric plants in the Ironton-Ashland-Huntington area. The area's high-energy needs are supplied by large coal-burning power plants located outside of the study area on the Ohio River and on its tributaries. The effect of pollutants emitted from these plants on inhabited sections of the study area is diminished by the distance of the plants from the population centers.

REVIEW OF PAST STUDIES

National Air Sampling Network

Both Ashland, Kentucky, and Huntington, West Virginia, are among the 150 cities included in the National Air Sampling Network (NASN).¹ The NASN is operated jointly by the National Center for Air Pollution Control, and state and local air pollution control agencies. Samples for suspended particulates have been obtained on a bi-weekly basis on alternate years since 1960 in Huntington, and since 1964 in Ashland. The data obtained from these samples are summarized in Table 1.

Table 1. SUMMARY OF NATIONAL AIR SAMPLING NETWORK DATA FOR SUSPENDED PARTICULATES IN HUNTINGTON, WEST VIRGINIA, AND ASHLAND, KENTUCKY

Station	Year	No. samples	Concentration, $\mu\text{g}/\text{m}^3$		Percent of time 150 $\mu\text{g}/\text{m}^3$ exceeded
			Maximum	Arith. Average	
Huntington, W. Va. (700 block of 4th Avenue)	1960	24	219	122	20
	1962	20	194	78	10
	1964	24	392	123	22
	1966	24	291	149	43
Ashland, Kentucky (340 W. 15th St.)	1964	24	455	179	53
	1966	25	423	167	43

Particulate Survey of Ironton, Ohio

At the request of the Ironton-Lawrence County Health Department, the Ohio Department of Health conducted a survey of particulate pollution in the city of Ironton during the period February 13 to August 29, 1964. Sampling was confined to four stations located within the city limits of Ironton. Measurements made for suspended particulates and dustfall are summarized in Tables 2 and 3.²

Table 2. SUMMARY OF OHIO DEPARTMENT OF HEALTH DATA FOR
SUSPENDED PARTICULATE IN IRONTON, OHIO, 2/13/64-8/29/64

Station	No. samples	Arithmetic average, $\mu\text{g}/\text{m}^3$		
		Total	Inorganic	Iron
General Hospital	42	176.3	113.5	10.5
Marting Hotel	41	130.1	75.5	7.6
Whitwell School	34	151.3	87.2	10.1
Pumphouse	30	170.4	85.5	9.3
Average all stations		156.4	91.1	9.3

Table 3. SUMMARY OF OHIO DEPARTMENT OF HEALTH DATA FOR SETTLEABLE
PARTICULATES (DUSTFALL) IN IRONTON, OHIO, 2/13/64-8/29/64

Station	No. samples	Arithmetic average, $\text{tons}/\text{mi}^2\text{-mo}$		
		Total	Inorganic	Iron
General Hospital	10	192.6	141.2	5.0
Marting Hotel	9	86.1	61.1	2.97
Whitwell School	9	104.8	75.1	4.1
Pumphouse	10	209.3	107.6	4.1
Near cement plant	3	275.0	201.0	4.5
Average all stations		139.9	90.6	4.1

Background Pollution Measurements in Ashland, Kentucky

As part of a State-wide survey to obtain data on air pollution background levels, the Kentucky Department of Health conducted short-term air quality tests at a single station located at 20th and Central Avenue in Ashland, Kentucky.³ Measurements were made for both suspended and settleable particulates as well as several gases during a 10-day period, August 18 - September 2, 1965. The test data, although representative of conditions particular to the actual collection period, showed values comparable with those obtained by the Public Health Service and reported herein in Section IV.

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II. CLIMATOLOGY OF STUDY AREA

TOPOGRAPHY

The Ironton-Ashland-Huntington area is located along the western foothills of the Appalachian Mountains at the confluence of the Ohio and Big Sandy Rivers. Within the area, the Ohio River averages a half-mile in width. The valley averages about 1 1/2 miles in width with surrounding ridges on both sides rising sharply 250 to 300 feet above the valley floor. Between Huntington and Kenova, the Ohio flows in a west-southwest direction and then bends northwestward toward Ashland and Ironton.

Nearly all of the major sources of air pollution in the survey area are located in the valley. In this area, the valley shape and depth has an important influence on the transport and dispersion of the air pollutants.

SOURCES OF CLIMATIC INFORMATION

The United States Weather Bureau has collected surface, winds aloft, and upper-air temperature-humidity data at the Tri-State Airport since December 1, 1961. The Tri-State Airport is located on a well-exposed plateau, about 3 miles southwest of Huntington. Before December 1961, official weather observations were obtained in downtown Huntington and at the Huntington Airport located in Ohio across the Ohio River from Huntington. The Tri-State Airport is 260 feet higher than the former downtown observation site and 268 feet above the Huntington Airport.

The Environmental Sciences Service Administration routinely publishes monthly climatological summaries for the Weather Bureau Station at the Tri-State Airport. In addition to the monthly summaries, a 3-year summary of winds at the Tri-State Airport and a similar summary covering 7 years at the Huntington Airport were obtained from the National Weather Records Center, Asheville, North Carolina. Finally, an amateur weather observer, Mr. Robert Harrod, provided valuable wind data, which he gathered over several years at Kenova, West Virginia.

WEATHER FACTORS RELATED TO AIR POLLUTION

The atmosphere disperses and dilutes air contaminants. The primary meteorological parameters that affect dispersion are wind direction, wind speed, and atmospheric stability. Other parameters such as ambient temperature, sunshine, and cloud cover influence dispersion principally through their effect on wind and stability, and thereby less directly affect dispersion potential.

Wind direction determines the direction of movement of pollutants, and its variability contributes to horizontal dispersion. The frequency of hourly wind directions over a reasonably long period is commonly used to indicate the patterns of air pollution impact over an area.

Wind speed directly affects the rate of dilution of air pollutants. Generally, the higher the wind speed, the lower the pollutant concentrations.

Stability of the atmosphere affects wind speed and direction variations, and determines the rate at which pollutants are dispersed vertically. Stability is commonly expressed in terms of temperature change with height. Vertical dispersion is poorest when the air is stable and the temperature increases with height to form a temperature inversion.

Wind Direction and Speed

Frequencies of hourly wind direction and speed at the Tri-State Airport for a period of 3 years and at the Huntington Airport for 7 years are shown in Figures 2 and 3. The patterns of wind at the two airports show marked differences that can largely be attributed to the relative influence of terrain.

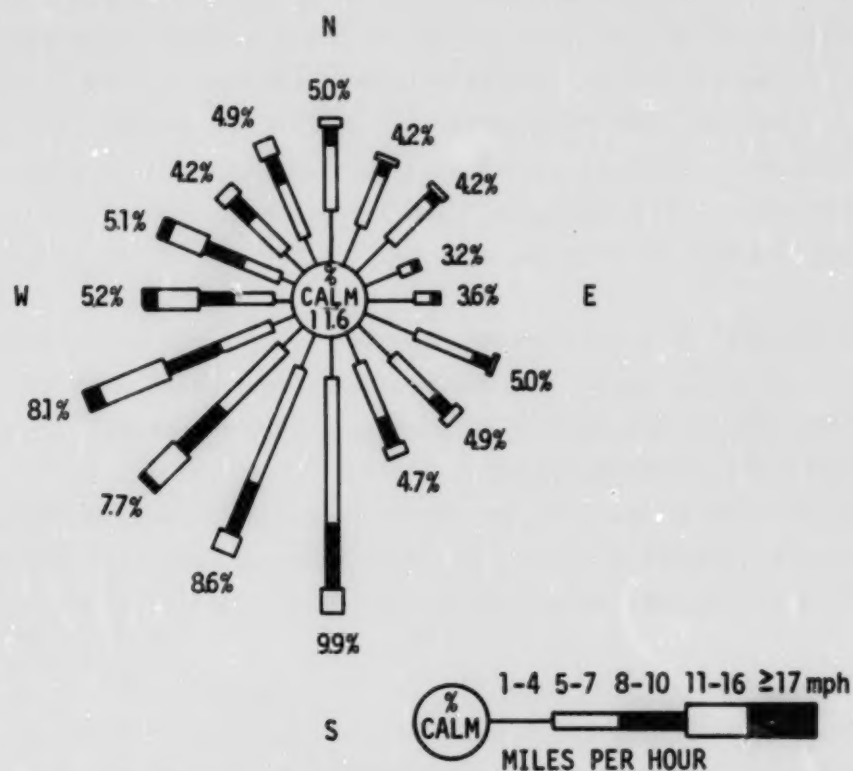


Figure 2. Annual wind rose for Tri-State Airport, West Virginia, January 1962 through December 1964.

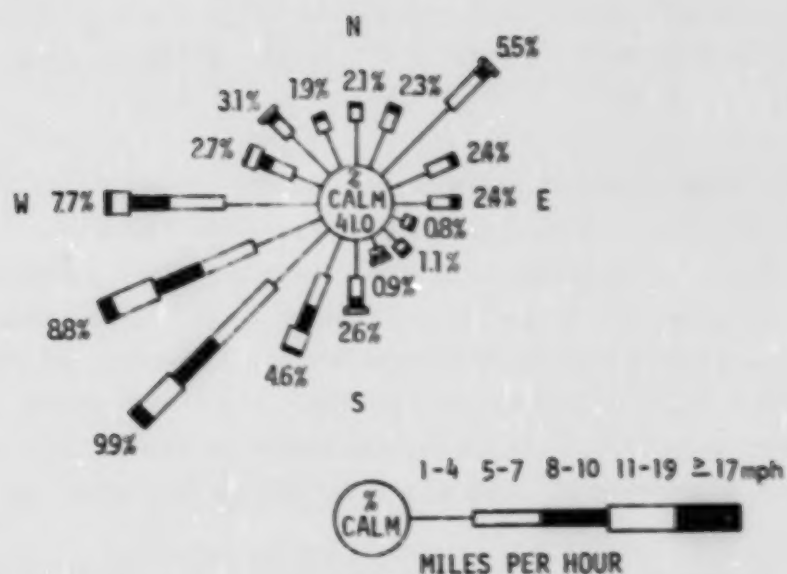


Figure 3. Annual wind rose for Huntington Airport at Chesapeake, Ohio, January 1948 through December 1964.

Wind flow at ridge level at the Tri-State Airport shows no evidence of being significantly influenced by local terrain features. The predominant winds are from the south through southwest; they occur about a third of the time. The average hourly wind speed at the Tri-State Airport is 6.2 miles per hour (mph).

At the Huntington Airport on the valley floor, wind flow is markedly influenced by the contour of the valley. The most frequent wind directions, southwest through west and northeast, approximately parallel the valley axis. The tendency of the winds to flow along the valley is indicative of channeling of the prevailing winds by the valley walls. Channeling, a common phenomenon in valley situations, is illustrated in Figure 4. Channeled flow was also evident in the wind observations made by Mr. Robert Harrod at Kenova, West Virginia.



Figure 4. Channeling of wind by a valley 4.

The mean hourly wind speed at the Huntington Airport was 3.5 mph, about half that at the Tri-State Airport. Lighter winds in the valley can be ascribed to sheltering by the valley walls.

Frequency of light winds is an important consideration in evaluating air pollution potential since the dilution capability of the atmosphere is inhibited with low wind speeds. Wind speeds of 7 mph or less are usually associated with significant accumulation of air pollution in urban areas. Wind speeds in the 0- to 7-mph range occurred at the Tri-State Airport 70 percent of the time and at the Huntington Airport 84 percent of the time. Light wind speeds at the two locations occurred more frequently during the nighttime hours. Seasonally, the most frequent occurrence of light winds was during the summer and fall.

The wind patterns at the two airports show that the air pollution potential in the valley is greater than at the higher, ridge elevations. Prevalent wind direction frequencies along the valley cause pollutant concentrations in the valley to be higher on an annual basis than if wind directions were more equally distributed. Furthermore, the frequent light winds in the valley cause greater accumulation of air pollutants.

Atmospheric Stability

Thermal stability or lapse rate, the change in temperature with height, significantly affects vertical mixing. During the day when the air is heated from below, air is exchanged by vertical mixing and pollutants near the surface are diluted. At night, the air near the ground cools so that temperature increases with height, thus a temperature inversion is formed and vertical dispersion of pollutants is at a minimum.

Temperature inversions have a tendency to occur more often and to be of longer duration in the valley than on the ridges. Under clear skies at night, lighter wind movement in the valley enhances inversion formation, and cold air drainage into the valley deepens the inversion layer. As a result, inversions in the valley will tend to last longer after sunrise than those that form at ridge level.

Hosler⁵ estimated the frequency of inversions based below 500 feet in the vicinity of the study area. He found such inversions occurring about 35 percent of the time. Hosler's study, however, was based on upper air data obtained at ridge-level airports in the region. A somewhat higher frequency of occurrence would reasonably be expected at valley locations.

Although insufficient data are available to estimate the duration of inversions in the valley, an estimate of the persistence can be obtained from some observations made by the Weather Bureau from June 1955 through May 1957⁶ at Shippingport, Pennsylvania. Shippingport, also located in the Ohio River Valley, about 180 miles upriver from the study area, has terrain features similar to those of the study area. The Shippingport data were obtained from temperature sensors located 30 feet above ground at valley and ridge levels to give the net temperature change with height over the 400-foot valley-ridge elevation interval. Figure 5 gives, on a seasonal basis, the percent of the temperature inversions that formed and persisted between the valley and ridge for extended time periods. It shows that inversions were generally most persistent in the fall. Inversions in the fall persisted for 8 hours or more in 33 percent of the cases and 4 hours or more in 54 percent of the cases.

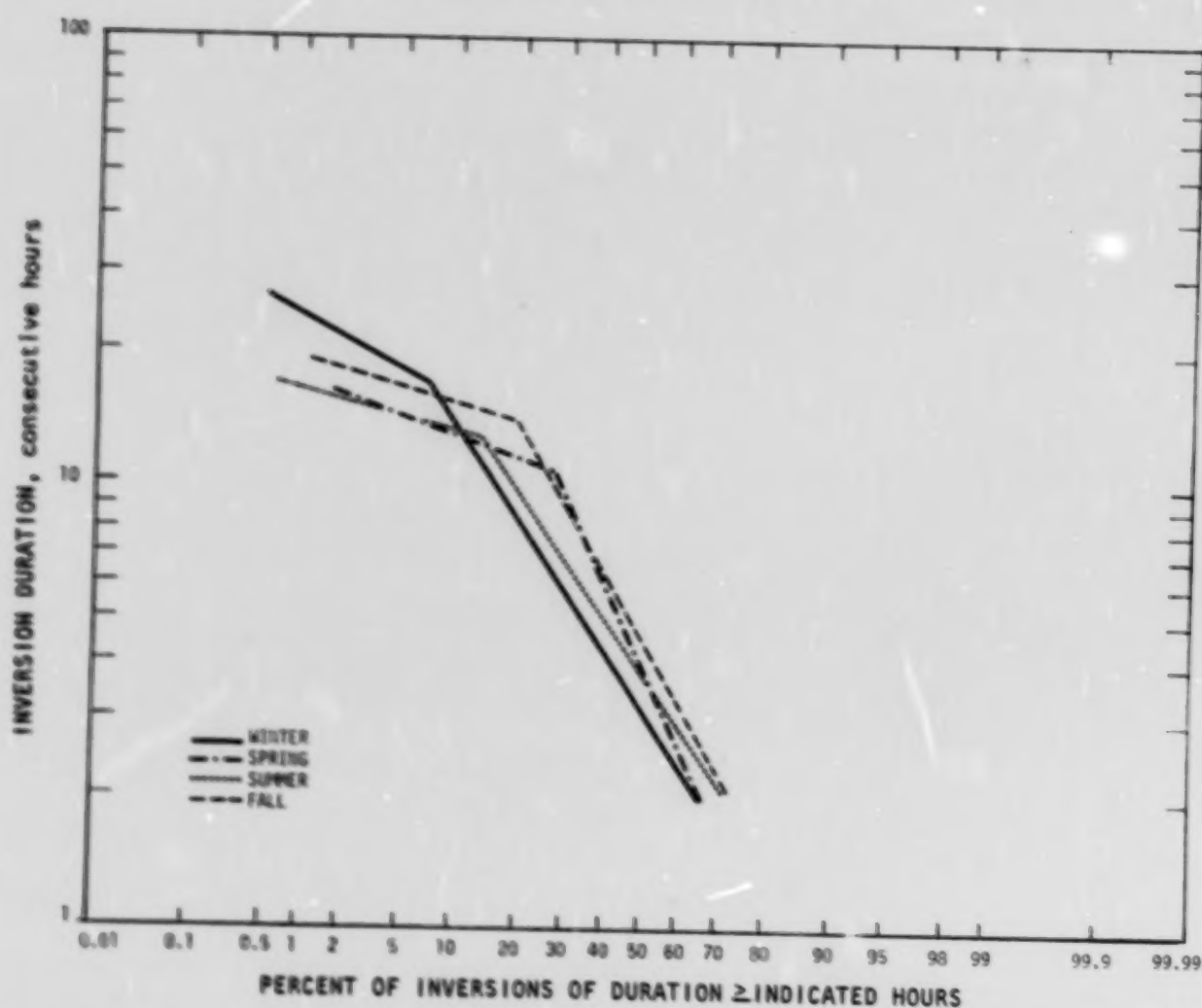


Figure 5. Persistence of temperature inversions at Shippingport, Pennsylvania, between Valley and Ridge stations, June 1955 through May 1957.

Stagnations

Periods of atmospheric stagnation are associated with slow-moving or stationary high-pressure cells. During such stagnations winds are light and skies are generally clear so that frequent and persistent inversions occur. Stagnations are conducive to the buildup of unusually high pollutant concentrations.

Stagnations occur relatively frequently in the Ironton-Ashland-Huntington area. East of the Rocky Mountains, only areas to the south along the Appalachian chain have more frequent stagnation periods.

About 54 stagnations lasting 4 days or more occurred in the vicinity of Ironton-Ashland-Huntington over the 30-year period from 1936 through 1965.⁷ This amounts to an average occurrence of nearly two such episodes per year. More than half of the cases (59%) occurred during August, September, and October.

III. PROJECT DESIGN

The objectives of the survey were to determine the nature, sources, extent, and effects of air pollution in the study area. To achieve these objectives, a program was undertaken to gather information through the activities discussed in the following paragraphs.

AIR SAMPLING MEASUREMENTS

A 17-station air sampling network, shown in Figure 6, was established to monitor ambient levels of airborne particulate matter and sulfur dioxide, the primary pollutants of concern. The sampling stations were located throughout the area primarily in population centers to provide data representative of residential exposures. A detailed description of the network and its operation are presented in Appendix A. The types of air pollution measurements and sampling equipment included at each station are listed in Table 4.

EMISSION INVENTORY

An emission inventory was conducted to locate and quantify particulate and sulfur dioxide emissions from industrial, commercial, governmental, and residential sources in the area. The inventory was to provide the following:

1. Identification of source emissions within the study area and definition of their location, magnitudes, and relative contribution of pollutants.
 2. Data for calculations of interstate transportation of pollutants and the magnitude of the impact of these emissions at selected receptor sites.
 3. Information on fuel-use distributional patterns and industrial emissions.
- The technique utilized is a modified rapid survey method.⁸ A detailed description of the procedure is included in Appendix B.

METEOROLOGICAL OBSERVATIONS

The United States Weather Bureau observations at the Huntington Tri-State Airport were augmented during the survey by surface wind direction and speed measurements at three sites in the valley. In addition, a series of meteorological soundings were made to obtain data on the vertical distribution of wind and temperature. The meteorological measurements provided information necessary for proper interpretation of the air sampling data. These data were also used to determine the "representativeness" of the 1965-1966 sampling period relative to the established normals for past years.

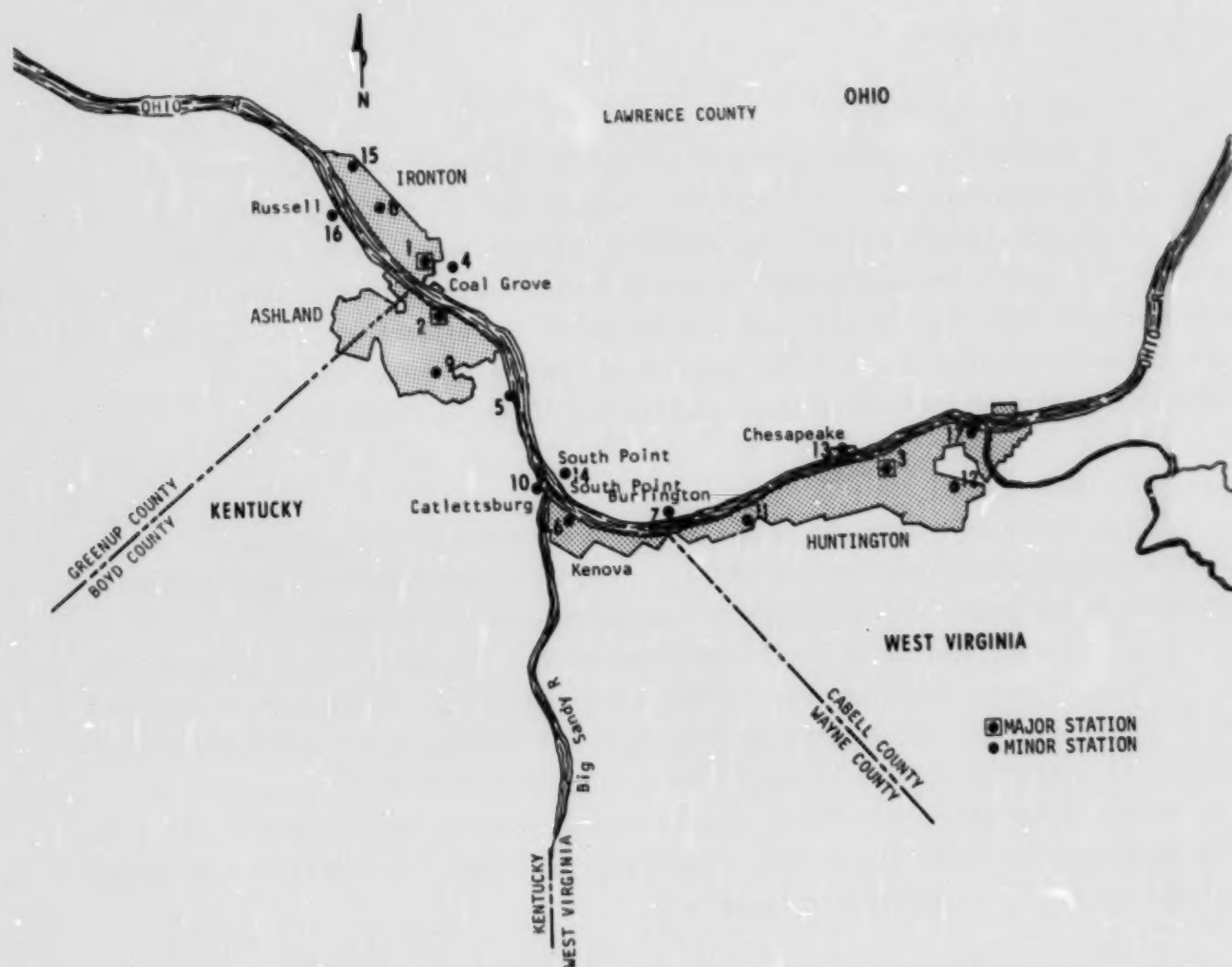


Figure 6. Locations of air sampling stations in study area.

Table 4. SAMPLING STATION LOCATIONS AND EQUIPMENT

Station	Sampling Equipment ^a
1 - Ironton, Ohio (south)	A, B, C, D, E, H
2 - Ashland, Kentucky	A, B, C, D, H
3 - Huntington, West Virginia	A, B, C, D, E, H
4 - Coal Grove, Ohio	B, C
5 - Ashland, Kentucky (southeast)	B, C
6 - Kenova, West Virginia	B, C, E
7 - Burlington, Ohio	B, C
8 - Ironton, Ohio (central)	C
9 - Ashland, Kentucky (south)	C
10 - Catlettsburg, Kentucky	C
11 - Huntington, West Virginia (west)	C
12 - Huntington, West Virginia (south)	C
13 - Chesapeake, Ohio	C
14 - South Point, Ohio	C
15 - Ironton, Ohio (north)	C
16 - Russell, Kentucky	C
17 - Huntington, West Virginia (east)	C

^a Equipment legend:

- A - Sulfur dioxide (SO₂), sequential sampler
- B - Suspended particulate, high-volume sampler
- C - Dustfall bucket, sulfation candle
- D - Material effects surveillance sites
- E - Meteorological instrumentation
- H - Soiling, AISI tape sampler

MATERIAL EFFECTS MEASUREMENTS

Material effects were measured utilizing static components, developed by National Center for Air Pollution Control personnel. These components provide semiquantitative information on types of air pollutants and their effects on specific materials. These devices were placed at sites in Ironton, Ohio; Ashland, Kentucky; and Huntington, West Virginia. The components at these three surveillance sites and the effect demonstrated by each are listed in Appendix A.

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IV. RESULTS OF COMPREHENSIVE SURVEY

PARTICULATE POLLUTANTS

Suspended Particulates

Suspended particulate matter in the atmosphere is composed of finely divided particles which normally remain airborne for long period of time and are carried by wind currents over long distances. Although these particles do not settle rapidly, they are deposited on all exposed surfaces by impaction and by thermal and electrostatic forces. Fine particles infiltrate homes, businesses, hospitals, and other buildings where they soil walls, furniture, clothing and other property.

One of the most noticeable effects of suspended particulates in the atmosphere is decreased visibility. In addition to direct visibility reduction, suspended particulates also can promote formation of fog and increase its persistence.

Atmospheric suspended particulate concentrations were measured with high-volume samplers at seven locations in the study area. Samples were collected over 24-hour periods starting at midnight. Frequency distribution of daily measurements at each station are presented in Appendix C, and a summary of these data appears in Table 5.

Table 5. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF TOTAL SUSPENDED PARTICULATES CONCENTRATIONS

Station	Operating period	No. obs	Concentration, $\mu\text{g}/\text{m}^3$											Geom. std. dev.	
			Min. value	Percent of time concentration is exceeded:							Max. value	Arith. mean	Std. dev.		
				90	70	50	30	16	10	1					
1 - Ironton (south)	9/65-9/66	290	26	73	122	170	232	310	365	690	1146	205	131	169	1.8
2 - Ashland	9/65-9/66	83	20	46	76	108	152	210	250	402	409	128	87	104	1.9
3 - Huntington	9/65-9/66	265	22	67	94	119	150	190	211	340	374	133	63	119	1.6
4 - Coal Grove	9/65-5/66	64	30	71	101	130	165	209	238	340	368	144	68	129	1.6
5 - Ashland (southeast)	9/65-5/66	58	27	42	64	82	101	128	150	310	313	90	48	80	1.6
6 - Kenova	9/65-9/66	264	31	58	86	112	151	191	225	391	622	133	33	112	1.7
7 - Burlington	9/65-5/66	64	29	39	54	69	88	110	127	209	213	77	68	60	1.6

Highest readings were found at South Ironton, where the average concentration for the entire year was 205 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$). Particulate levels in the adjacent community of Coal Grove were second highest, with an annual average of 144 $\mu\text{g}/\text{m}^3$.

Values in excess of $100 \mu\text{g}/\text{m}^3$ were recorded more than 50 percent of the time at five of the seven stations. Levels greater than $150 \mu\text{g}/\text{m}^3$ occurred at the South Ironton station 58 percent of the time. Coal Grove exceeded that level 37 percent of the time; Ashland, 32 percent of the time; and Huntington and Kenova, 30 percent. A detailed breakdown for all stations showing percent of time that selected concentration levels were exceeded is given in Table 6.

Seasonal means of suspended particulate measurements are given in Table 7. Values generally are highest during the autumn season, a period normally associated with meteorological conditions unfavorable for the rapid dispersion of pollutants.

Table 6. PERCENT OF CONCENTRATIONS EXCEEDING SPECIFIC VALUES -
SUSPENDED PARTICULATE BY HIGH-VOLUME SAMPLER

Station	Percent of days exceeding:				
	$65 \mu\text{g}/\text{m}^3$	$80 \mu\text{g}/\text{m}^3$	$100 \mu\text{g}/\text{m}^3$	$120 \mu\text{g}/\text{m}^3$	$150 \mu\text{g}/\text{m}^3$
1 - Ironton (south)	91	86	80	73	58
2 - Ashland	77	66	54	43	32
3 - Huntington	92	80	64	49	30
4 - Coal Grove	92	84	72	58	37
5 - Ashland (southeast)	69	52	33	14	10
6 - Kenova	85	74	60	51	30
7 - Burlington	55	39	20	11	5

Table 7. SUSPENDED PARTICULATE SEASONAL ARITHMETIC AND GEOMETRIC MEANS -
BY HIGH-VOLUME SAMPLER ($\mu\text{g}/\text{m}^3$)

Station	Arithmetic mean					Geometric mean				
	Sept.-Nov.	Dec.-Feb.	Mar.-May	June-Aug.	Sept.	Sept.-Nov.	Dec.-Feb.	Mar.-May	June-Aug.	Sept.
	1965	1965-1966	1966	1966	1966	1965	1965-1966	1966	1966	1966
1 - Ironton (south)	213	194	190	212	259	188	143	151	189	243
2 - Ashland	143	99	132	114	165	111	81	110	97	127
3 - Huntington	145	129	132	117	163	129	123	119	110	143
4 - Coal Grove	153	148	136	--	--	138	134	120	--	--
5 - Ashland (southeast)	97	91	86	--	--	88	75	78	--	--
6 - Kenova	129	117	127	165	225	117	102	111	142	182
7 - Burlington	81	83	72	--	--	71	78	66	--	--

Suspended Particulate Metals

Composites of suspended particulate filter samples collected September 9 through October 8, 1965, for each of the seven stations, were analyzed for metal content. These results are presented in Table 8, along with National Air

Sampling Network (NASN) average and maximum concentrations for their nationwide network of urban stations during 1964-1965.¹ Results show that South Ironton samples were highest in iron content, 34 $\mu\text{g}/\text{m}^3$. This value for a monthly composite sample is considerably in excess of the maximum 24-hour value obtained nationwide by the NASN during 1964-1965. The Huntington station 1-month composite sample had nickel content more than twice as high and a chromium content about 1-1/2 times as high as the NASN maximum 1-day value. Five of the seven stations yielded values for individual metals that exceeded the NASN average for all urban stations in 1965.

Table 8. ANALYSIS OF RESULTS OF METAL-CONTENT SUSPENDED PARTICULATE SAMPLES COLLECTED IN THE STUDY AREA ($\mu\text{g}/\text{m}^3$)

Station	Average particulates	Iron	Chromium	Manganese	Nickel	Zinc
1-Ironton(south)	208	34	0.3	0.61	0.05	4.0
2-Ashland	84	1	-	0.08	0.02	-
3-Huntington	118	6	0.5	0.73	1.20	2.0
4-Coal Grove	147	2	-	0.43	0.02	-
5-Ashland (southeast)	89	0.5	-	0.05	0.03	-
6-Kenova	116	1	-	0.06	0.05	-
7-Burlington	68	1	-	0.08	0.06	0.5
NASN average 1964-1965	105	1.58	0.015	0.10	0.034	0.67
NASN maximum 1964-1965 ^b	1254	22.0	0.33	9.98	0.460	58.00

^aDashes indicate that no analysis was performed.

^b24-hour value.

Settleable Particulates

Dustfall is determined by weighing the particles which accumulate in open containers exposed for a month. It is composed of coarse particles that settle rapidly from the air, generally within short distances from their sources. Particulate material deposited in this fashion causes soiling, promotes deterioration of materials, and generally creates a significant nuisance. The dirtiness of heavily polluted areas often is attributed to settleable particulates.

Settleable particulate was measured on a monthly basis at 17 stations using dustfall collectors. Data obtained are reported in tons per square mile per month ($\text{tons}/\text{mi}^2\text{-mo}$) and are summarized in Table 9. The highest dustfall rates, both maximum and average values, were reported for the South Ironton station.

Table 9. MONTHLY AVERAGES OF SETTLEABLE PARTICULATE (DUSTFALL) MEASURED FROM
SEPTEMBER 1965 TO SEPTEMBER 1966

Station	No. obs	Dustfall, tons/mi ² -mo					Geom std dev
		Min. value	Max. value	Arith Mean	Std dev	Geom Mean	
1 - Ironton (south)	13	36	98	55	19	53	1.5
2 - Ashland	13	12	64	23	13	21	1.3
3 - Huntington	12	15	33	22	5	21	1.4
4 - Coal Grove	12	19	46	32	9	31	1.4
5 - Ashland (southeast)	13	4	36	18	9	16	1.8
6 - Kenova	12	13	23	18	3	18	1.2
7 - Burlington	11	4	13	8	3	7	1.4
8 - Ironton (central)	13	10	30	21	7	20	1.4
9 - Ashland (south)	13	1	23	11	6	9	1.8
10 - Catlettsburg	13	13	30	20	5	20	1.3
11 - Huntington (west)	12	8	23	15	5	14	1.3
12 - Huntington (south)	13	3	19	10	4	9	1.6
13 - Chesapeake	13	10	27	16	4	15	1.3
14 - South Point	8	12	27	20	5	20	1.4
15 - Ironton (north)	11	5	17	11	4	10	1.4
16 - Russell	12	9	28	13	6	12	1.6
17 - Huntington (east)	13	9	22	15	4	15	1.2

Seasonal means for settleable particulate are shown in Table 10.

Table 11 lists the percent of recorded values for each station that exceeds specific levels.

At South Ironton every reading exceeded 35 tons/mi²-mo. The next highest station was Coal Grove where 58 percent of the values were greater than 30 tons/mi²-mo, and 33 percent exceeded 35 tons/mi²-mo. Two other sites, Ashland and Southeast Ashland each exceeded 35 tons/mi²-mo once during the 13-month sampling period.

Table 10. SEASONAL ARITHMETIC MEAN SETTLEABLE PARTICULATE (DUSTFALL) AT ALL STATIONS

Station	Mean dustfall, tons/mi ² -mo				
	Sept.-Nov.	Dec.-Feb.	Mar.-May	June-Aug.	Sept.
	1965	1965-1966	1966	1966	1966
1 - Ironton (south)	56	65	47	55	50
2 - Ashland	30	21	27	19	25
3 - Huntington	19	22	26	20	24
4 - Coal Grove	25	32	34	33	38
5 - Ashland (southeast)	14	22	16	17	31
6 - Kenova	17	15	20	18	23
7 - Burlington	5	6	9	8	11
8 - Ironton (central)	23	23	23	15	24
9 - Ashland (south)	5	10	17	10	21
10 - Catlettsburg	16	22	21	22	23
11 - Huntington (west)	12	11	18	16	21
12 - Huntington (south)	7	7	13	12	19
13 - Chesapeake	16	13	21	14	14
14 - South Point	14	-	22	22	-
15 - Ironton (north)	10	10	13	8	17
16 - Russell	13	12	14	10	20
17 - Huntington (east)	17	14	17	12	19

Table 11. PERCENT OF MONTHS SETTLEABLE PARTICULATE (DUSTFALL)
EXCEEDED SPECIFIC VALUES

Station	Percent of months exceeding:				
	15	20	25	30	35
	tons/mi ² -mo	tons/mi ² -mo	tons/mi ² -mo	tons/mi ² -mo	tons/mi ² -mo
1 - Ironton (south)	100	100	100	100	100
2 - Ashland	85	46	15	8	8
3 - Huntington	92	50	25	8	0
4 - Coal Grove	100	92	75	58	33
5 - Ashland (southeast)	54	38	23	15	8
6 - Kenova	75	25	0	0	0
7 - Burlington	0	0	0	0	0
8 - Ironton (central)	77	54	23	15	0
9 - Ashland (south)	31	15	0	0	0
10 - Catlettsburg	92	46	15	0	0
11 - Huntington (west)	42	17	0	0	0
12 - Huntington (south)	15	0	0	0	0
13 - Chesapeake	46	8	8	0	0
14 - South Point	88	50	25	0	0
15 - North Ironton	9	0	0	0	0
16 - Russell	25	8	8	0	0
17 - Huntington (east)	53	15	0	0	0

Particulate Soiling Index

Soiling index was measured at South Ironton, Ashland, and Huntington using AISI sequential filter-paper tape samplers. Data obtained over 2-hour averaging periods are shown in Table 12. These results indicate only slight variation between measured levels at the three stations.

Table 12. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF BI-HOURLY SOILING INDEX

Station	Operating period	No. obs.	Soiling Index, Cohs/1000 lineal feet ^a											
			Min. value	Percent of time values exceeded:							Max. value	Arith. mean	Std. dev.	Geom. mean
				90	70	50	30	10	10	1				
1 - Ironton (south)	12/85-6/86	1379	<0.1	0.2	0.4	0.6	1.2	1.8	2.3	4.6	6.6	1.1	0.9	0.7
2 - Ashland	12/85-5/86	898	<0.1	0.2	0.4	0.7	1.2	1.9	2.4	4.6	6.6	1.1	1.0	0.7
3 - Huntington	12/85-5/86	642	<0.1	0.1	0.3	0.4	1.1	1.2	1.6	2.7	4.4	0.7	0.7	0.4

^aCoefficient of haze per 1000 lineal feet of sampled air.

Table 13 gives the percent of time that specific values were exceeded. South Ironton and Ashland had values in excess of 4.0 Cohs, ordinarily considered an extremely heavy loading, 2 percent of the time.

Table 13. PERCENT OF SOILING INDEX VALUES WITHIN SPECIFIC RANGES

Soiling index range, Cohs/1000 lineal feet	Percent values in range		
	Ironton	Ashland	Huntington
0.0 - 0.4	27	26	49
0.5 - 0.9	35	33	26
1.0 - 1.9	27	24	18
2.0 - 2.9	6	12	5
3.0 - 3.9	3	3	2
4.0 plus	2	2	1

GASEOUS POLLUTANTS

Sulfur Dioxide

Sulfur dioxide (SO₂) in the atmosphere accelerates corrosion of metals and other materials, damages sensitive plants and irritates human sensory and respiratory systems. It is emitted predominantly from the combustion of sulfur-bearing fuels for heat and power.

Sulfur dioxide was measured for 2-hour sequential periods at South Ironton, Ashland, and Huntington. The results, determined by West-Gaeke colormetric method, are summarized in Table 14. Frequency distribution curves for the sulfur dioxide data are presented in Appendix C.

Table 14. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF SULFUR DIOXIDE CONCENTRATIONS - 2-HOUR AVERAGES

Station	Operating period	Concentration, ppm										Max. value	Arith. mean	Geom. mean	Std. dev.	Geom. std. dev.
		No. obs.	Min. value	Percent of time $\geq$ stated value:												
				90	70	50	30	16	10	1						
1 - Ironton (south)	8/65-9/66	1213	<0.01	<0.01	<0.01	0.01	0.01	0.02	0.02	0.07	0.12	0.01	0.01	0.01	0.001	
2 - Ashland	8/65-1/66	768	<0.01	<0.01	<0.01	0.01	0.01	0.02	0.02	0.05	0.07	0.01	0.01	0.01	0.001	
3 - Huntington	8/65-1/66	779	<0.01	<0.01	<0.01	0.01	0.01	0.02	0.03	0.09	0.14	0.01	0.01	0.02	0.001	

An arithmetic average concentration of 0.01 ppm was reported for all three stations. The highest 2-hour reading, 0.14 ppm, was recorded at Huntington. South Ironton had a maximum reading of 0.12 ppm.

Monthly sulfation rates were determined at 17 stations using lead peroxide candles. The sulfation network was used to provide a study-wide indication of sulfur dioxide levels. Data are reported in milligrams of sulfur trioxide per 100 square centimeters (exposed candle area) per day and are summarized in Table 15. These results are consistent with the moderate SO_2 levels measured at the three stations where colormetric determinations were made. Long-term levels of SO_2 throughout the study area are not excessive. Highest sulfation values were recorded at South Ironton where levels in excess of 1.0 mg $\text{SO}_3/100 \text{ cm}^2$ -day occurred 17 percent of the time.

Hydrogen Sulfide

Hydrogen sulfide (H_2S) is a sulfur gas emitted from coke ovens and some other industrial operations. It has the characteristic effect of darkening lead pigment paints and tarnishing silver; but perhaps more important is its offensive odor even in very low concentrations.

Hydrogen sulfide measurements made with lead acetate reagent impregnated filter tapes were taken at five sites in the study area. Intermittent sampling was conducted from December 1965 to September 1966. Results are given in Table 16.

Table 15. SULFATION NETWORK RESULTS - MONTHLY AVERAGES
SEPTEMBER 1965 - SEPTEMBER 1966

Station	No. obs	Sulfation, mg SO ₃ /100 cm ² -day				
		Min. value	Max. value	Arith mean	Std. dev	Geom mean
1 - Ironton (south)	12	0.5	5.2	1.2	1.3	1.0
2 - Ashland	13	0.2	0.8	0.4	0.2	0.4
3 - Huntington	13	0.2	0.6	0.4	0.1	0.4
4 - Coal Grove	13	0.3	2.9	0.8	0.7	0.6
5 - Ashland (southeast)	13	0.1	0.6	0.3	0.2	0.2
6 - Kenova	13	0.1	0.6	0.4	0.1	0.3
7 - Burlington	13	0.1	0.4	0.2	0.1	0.2
8 - Ironton (central)	13	0.1	0.8	0.4	0.2	0.4
9 - Ashland (south)	13	0.1	0.6	0.3	0.1	0.2
10 - Catlettsburg	12	0.2	0.8	0.4	0.2	0.3
11 - Huntington (west)	13	0.2	0.8	0.3	0.2	0.3
12 - Huntington (south)	13	0.1	0.5	0.2	0.1	0.2
13 - Chesapeake	13	0.1	0.7	0.3	0.2	0.3
14 - South Point	10	0.2	0.6	0.4	0.1	0.3
15 - Ironton (north)	11	0.2	1.9	0.5	0.4	0.4
16 - Russell	11	0.1	1.5	0.4	0.4	0.3
17 - Huntington (east)	13	0.2	0.8	0.5	0.2	0.4

Table 16. HYDROGEN SULFIDE RESULTS

Station	Operating period	No. obs	Concentration, ppm	
			Arith avg	Maximum
1- Ironton (south)	12/15/65-1/20/66	676	0.003	0.200
	4/18/66-5/19/66	598	0.007	0.280
	8/18/66-9/11/66	642	0.001	0.051
3- Huntington	4/ 2/66-5/18/66	683	<0.001	0.006
4- Coal Grove	1/ 4/66-1/23/66	375	0.001	0.006
18-Bellefonte ^a	2/ 7/66-4/18/66	1186	0.001	0.006
19-Sheridan ^a	2/14/66-2/28/66	333	0.001	0.006
	4/ 1/66-5/13/66	793	0.001	0.007
	8/ 5/66-9/ 5/66	717	<0.001	0.013

^aThis station had hydrogen sulfide measurements only.

The highest readings were obtained at South Ironton. Although the average values for all five stations were less than 0.01 ppm, hourly concentrations reached values considerably above these averages on several occasions, particularly at South Ironton. Concentrations as high as 0.20 and 0.28 ppm were measured at the South Ironton station. Observation of occasional high H_2S levels at the South Ironton station was consistent with reported incidents of odor nuisances. Special H_2S measurements were made at Sheridan, Ohio, and Bellefonte, Kentucky, in response to odor complaints received from area residents during the survey period. Moderate values were obtained during the sampling periods. Values higher or lower than those reported may have occurred for short intervals during the sampling periods, or at other times at these two sites.

EMISSION INVENTORY

An inventory of particulate and sulfur oxides emitted to the atmosphere from fuel combustion by stationary and mobile sources, municipal and industrial refuse burning, and manufacturing processes was conducted for the five counties in the study area. Data are for 1965; this is the latest year for which emissions data were available when the emissions inventory was initiated. The study area was subdivided into eight emission reporting zones consisting of the three major cities and the five county areas outside the cities. Emission zones are shown in Figure 7.

The results of the emission survey show that more than 49,000 tons of sulfur oxides (calculated as SO_2 and referred to as SO_x) and approximately 50,000 tons of particulate were discharged to the atmosphere from sources in the study area during 1965. These emissions, delineated by source category and emission zone, are shown in Tables 17 and 18. More than half of both sulfur oxides and particulate pollutants are emitted in the Ohio portion of the study area. The Kentucky portion is responsible for 35 to 40 percent of the emissions of these pollutants while the West Virginia portion contributes about 10 percent. The proportional contribution of each pollutant (particulates and SO_x) by each of the three states is shown in Figure 8.

Emissions of SO_x are shown by source category in Figure 9. Ninety-two percent of the SO_x emitted in the study area is due to fuel combustion by stationary sources. The remaining 8 percent of the SO_x is emitted by motor vehicles and industrial process losses. The SO_x emissions from fuel combustion reflect both quantities and sulfur contents of the fuel. For any surveyed source, the reported fuel sulfur content was used for emission calculations. For other sources, an average sulfur content of 2 percent was used for both coal and residual fuel oil.

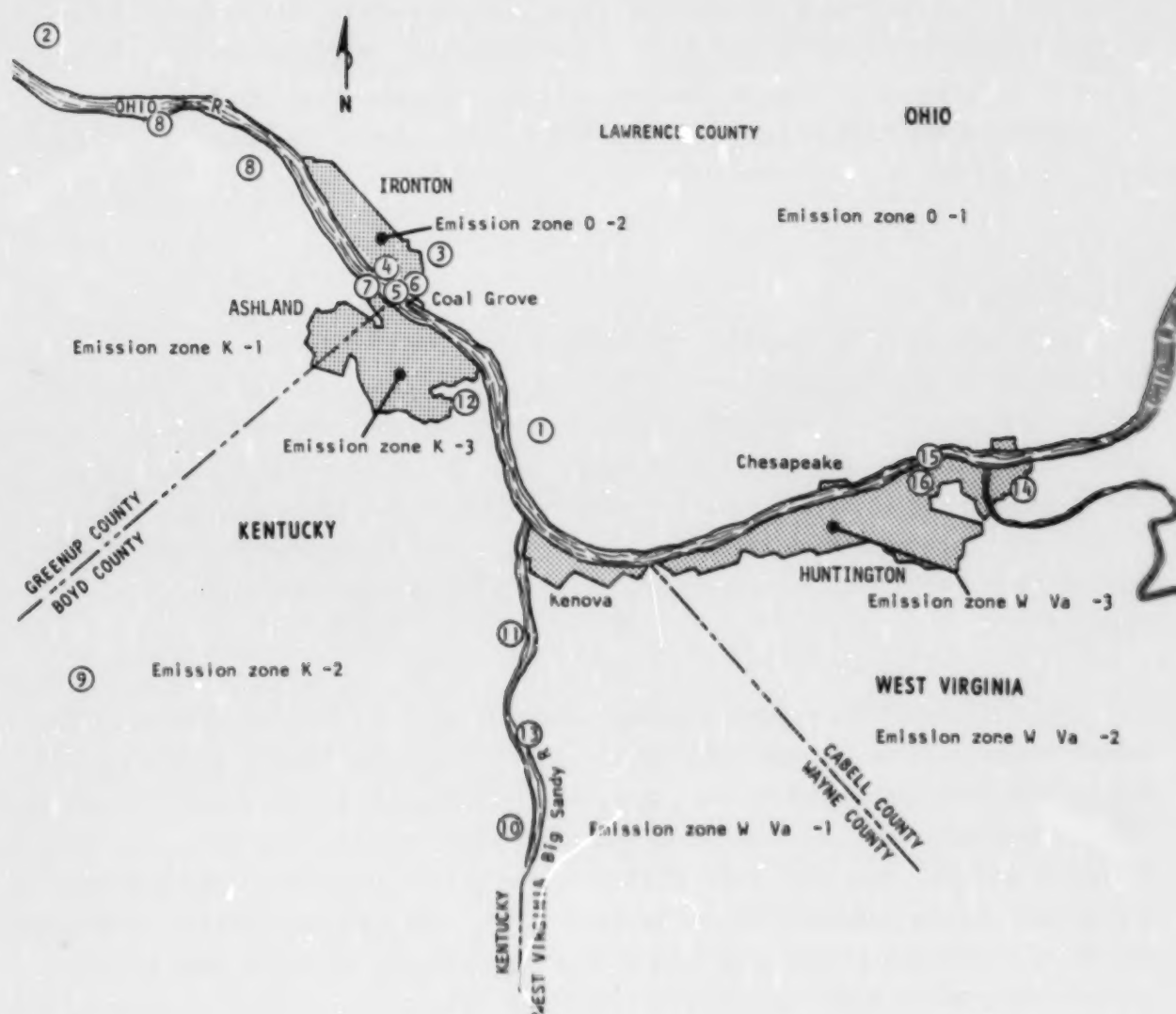


Figure 7. Emission zones and major point sources for the study area.

Table 17. SULFUR OXIDES EMISSIONS IN STUDY AREA DURING 1965 (tons/year)

Source category	Emission zones											Area total
	Ohio			Kentucky			West Virginia			Total		
	0-1	0-2	Total	K-1	K-2	K-3	Total	W Va-1	W Va-2		W Va-3	
Industrial fuel												
Coal	18,500	750	19,250	1,000	1,600	1,800	4,400	1,200	38	900	2,138	25,788
Dist. oil	150	31	181	5	38	64	107	30	70	190	290	578
Resid. oil	65	110	175	5	840	69	914	10	20	53	83	1,172
Natural gas	2	1	3	0	2	0	2	0	Neg.	Neg.	Neg.	5
Other	63	2,000	2,063	620	8,000	2,300	10,920	0	0	0	0	12,983
Total*	18,800	2,900	21,700	1,600	10,500	4,200	16,300	1,200	100	1,100	2,500	40,500
Commercial and government fuel												
Coal	90	110	200	0	100	0	100	0	0	85	85	385
Dist. oil	120	150	270	82	90	210	382	35	28	270	333	985
Resid. oil	4	5	9	1	1	3	5	9	7	66	82	96
Natural gas	0	0	0	0	0	0	0	0	Neg.	Neg.	Neg.	Neg.
Total*	200	300	500	100	200	200	500	40	30	400	500	1,500
Residential fuel												
Coal	990	91	1,081	5	360	5	370	520	730	120	1,370	2,821
Dist. oil	150	15	165	19	13	18	50	12	2	24	38	253
Natural gas	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0	Neg.	1	1	1
Total*	1,100	100	1,200	20	400	20	400	500	700	100	1,400	3,100
Total fuel consumption												
Coal	19,600	960	20,560	1,040	2,080	1,810	4,930	1,700	770	1,130	3,600	29,090
Dist. oil	430	200	630	110	140	290	540	77	100	480	657	1,827
Resid. oil	69	120	189	6	840	72	918	19	27	120	166	1,273
Natural gas	2	1	3	0	2	0	2	0	Neg.	1	1	6
Other	63	1,990	2,053	620	8,000	2,260	10,880	0	0	0	0	12,933
Total*	20,200	3,300	23,400	1,800	11,100	4,400	17,300	1,800	900	1,700	4,400	45,100
Process	38	1,800	1,838	630	900	0	1,530	0	0	0	0	3,368
Refuse	11	6	17	8	14	6	28	8	9	14	31	76
Transportation	82	52	134	51	23	90	164	40	54	150	244	542
Grand total*	20,300	5,100	25,400	2,500	12,000	4,500	19,000	1,800	1,000	1,900	4,700	49,100

^aColumn totals have been rounded to three significant figures.

Table 18. PARTICULATE EMISSIONS IN STUDY AREA DURING 1965 (tons/year)

Source category	Emission zones												Area Total
	Ohio			Kentucky			West Virginia			Total			
	0-1	0-2	Total	K-1	K-2	K-3	Total	W Va-1	W Va-2		W Va-3		
Industrial fuel													
Coal	11,100	900	12,000	690	1,500	1,840	4,390	1,130	25	310	1,465	17,855	
Dist. oil	26	1	27	Neg.	1	2	3	1	2	5	8	38	
Resid. oil	2	3	5	Neg.	21	2	23	Neg.	Neg.	1	1	29	
Natural gas	110	50	160	58	100	2	160	2	3	12	17	337	
Other	1	290	291	48	100	65	213	0	0	0	0	504	
Total ^a	11,200	1,200	12,500	800	1,700	1,900	4,400	1,100	30	300	1,500	18,400	
Commercial and government fuel													
Coal	61	74	135	0	90	0	90	0	0	56	56	281	
Dist. oil	3	4	7	2	2	5	9	1	1	7	9	25	
Resid. oil	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	2	2	2	
Natural gas	120	2	122	2	1	5	8	1	2	16	19	149	
Total ^a	200	80	300	4	100	10	100	2	3	100	100	500	
Residential fuel													
Coal	260	24	284	1	95	1	97	140	190	32	362	743	
Dist. oil	6	1	7	1	Neg.	1	2	Neg.	Neg.	1	1	10	
Natural gas	6	7	13	6	5	13	24	4	8	37	49	86	
Total ^a	300	39	399	8	100	20	100	100	200	100	400	800	
Total fuel consumption													
Coal	11,400	1,000	12,400	690	1,690	1,840	4,220	1,270	220	390	1,880	18,500	
Dist. oil	35	6	41	3	3	8	14	2	3	13	18	73	
Resid. oil	2	3	5	Neg.	21	2	23	Neg.	Neg.	3	3	31	
Natural gas	240	59	299	66	110	20	196	2	13	65	85	580	
Other	1	290	291	48	100	65	213	0	0	0	0	504	
Total ^a	11,700	1,400	13,000	800	1,900	1,900	4,700	1,300	200	500	2,000	19,700	
Process	11,400	1,720	13,120	8,230	1,490	1,370	11,090	84	51	1,650	1,785	25,995	
Refuse	460	240	700	320	320	230	870	330	350	880	1,560	3,130	
Transportation	130	84	214	78	35	140	253	65	90	250	405	872	
Grand Total	23,700	3,400	27,100	9,400	3,800	3,700	16,900	1,800	700	3,300	5,700	49,700	

^aColumn totals have been rounded to three significant figures.

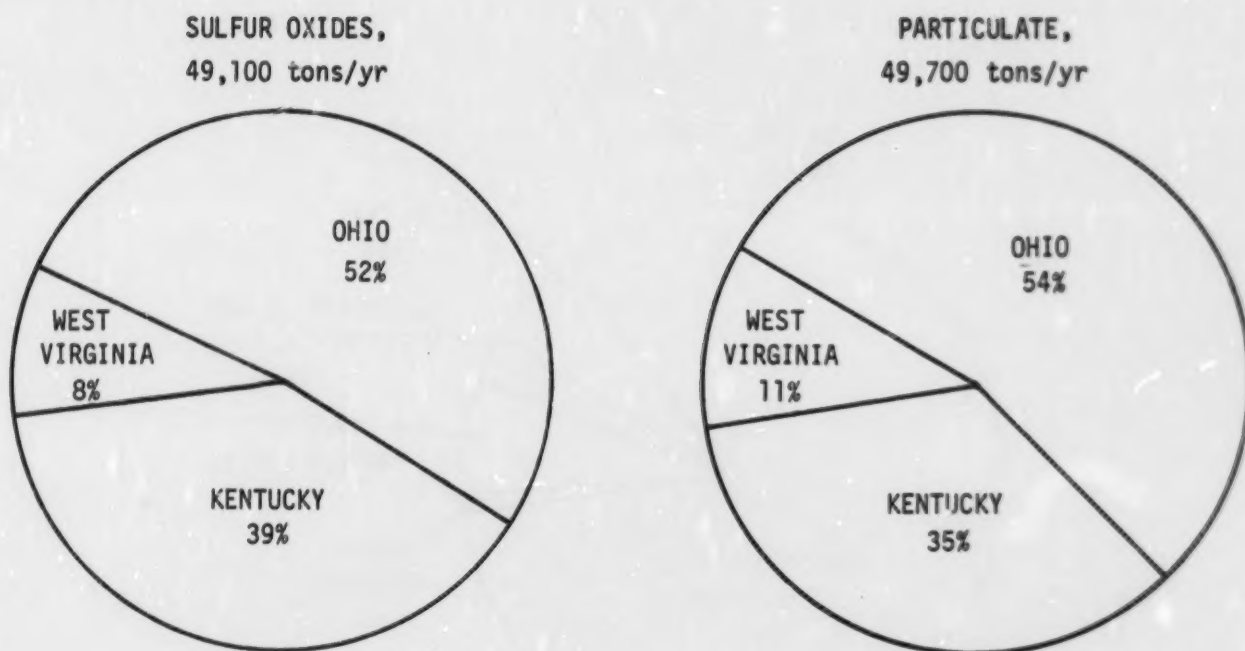


Figure 8. Sulfur oxides and particulates emissions in the study area by geographical origin

As shown in Figure 9, fuel combustion by stationary sources contributes 40 percent of the particulate emissions, industrial process losses contribute 52 percent, and motor vehicles and refuse disposal are responsible for the remaining 8 percent of the particulate emissions. The particulate emissions in the study area are primarily solid matter except for liquid aerosols emitted from sulfuric acid manufacturing. Particulate emissions include both organic and inorganic materials from fuel combustion and coking operations, charred cellulose and ash from incineration, oxidized gasoline additives (mainly lead compounds) from motor vehicles, mineral dust from cement batching plants, metallurgical fumes, catalyst fines, and organic and inorganic dusts from industrial processes.

The particulate inventory for combustion reflects fuel quantities, ash contents and, when controls are employed, control equipment efficiencies. For any surveyed source, the reported ash content and control equipment efficiency were used for emission calculations. Average ash contents (10 percent, by weight) and control equipment efficiencies were used for coal-burning sources for which specific data were not available. For most sources it was assumed that no control equipment is used on coal-fuel units.

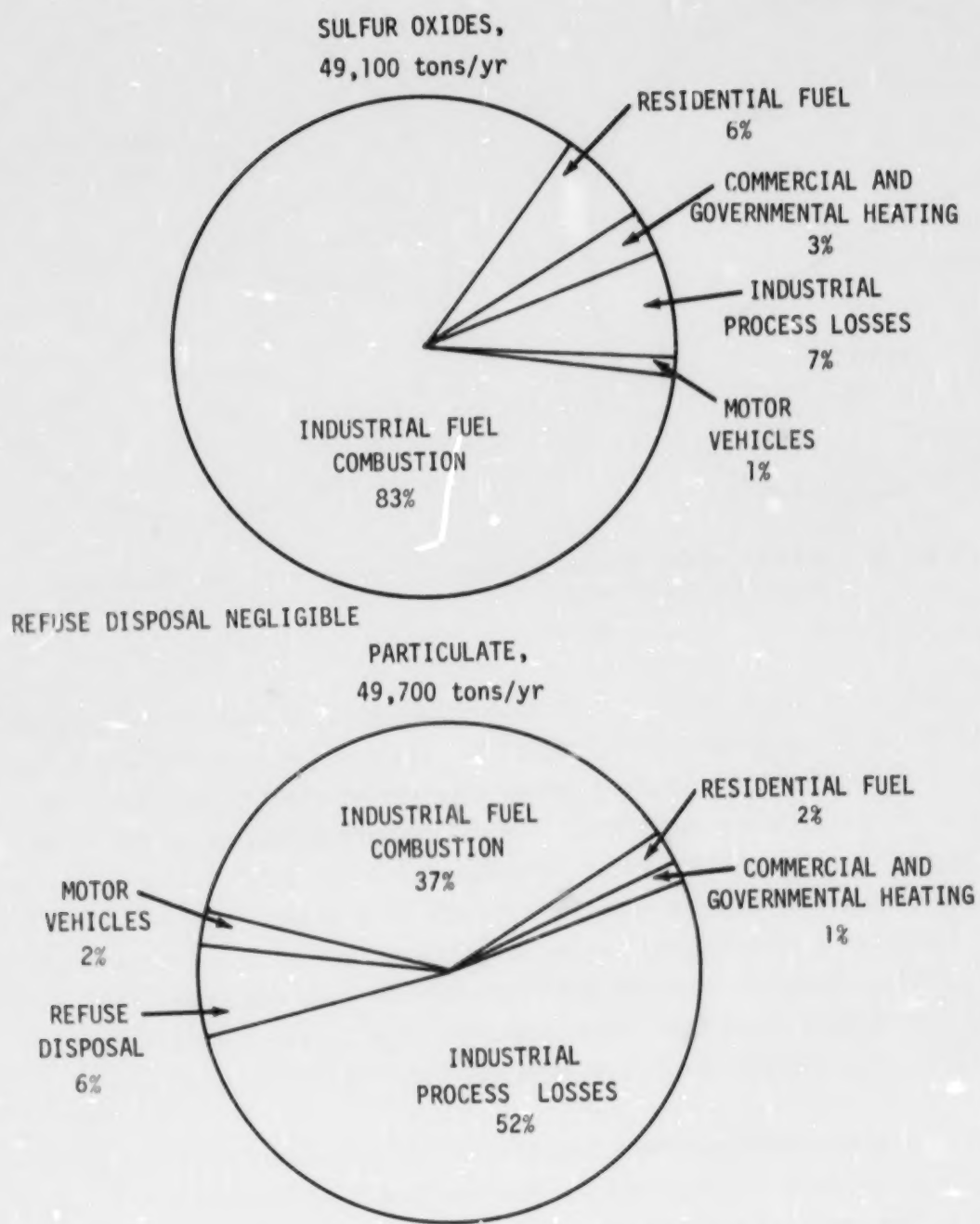


Figure 9. Sulfur oxides and particulate emissions in the study area by various sources

Emission From Fuel Combustion

Coal, fuel oil, natural gas and industrial fuel gas were considered to be the only significant types of fuel used in the study area for space, water, and process heating. Quantities of these fuels burned are listed by emission zone and source type in Table 19. Emissions by fuel type are listed in Tables 17 and 18 and are shown by percentage in Figure 10. Coal was found to contribute 65 percent of the 45,000 tons of SO_x emissions and 94 percent of the 20,000 tons of particulate emissions from fuel combustion. Burning distillate fuel oil contributes 4 percent of the SO_x emissions and less than 0.5 percent of the particulate emissions from fuel combustion. Residual fuel oil contributes 3 percent of the SO_x emissions, and its particulate emissions are negligible. The use of natural gas for all phases of heating and power generation yields negligible amounts of SO_x and 3 percent of the particulate emissions. The balance of the sulfur oxides and particulate emissions from fuel combustion come from miscellaneous industrial fuels such as coke, coke oven gas, and a high-sulfur fuel gas derived as a by-product from oil refining.

When the emissions from fuel combustion are separated into source types, industrial fuel burning is responsible for 90 percent of the area SO_x emissions and 94 percent of the particulate emissions, as shown in Figure 11. Residential heating contributes another 7 percent and 4 percent of the SO_x and particulate emissions, respectively. Commercial and governmental heating accounts for the balance of the fuel combustion emissions.

Of the fuel used in the area, industrial operations consume 92 percent of the coal, 53 percent of the distillate fuel oil, 92 percent of the residual oil, and 67 percent of the natural gas. Residential use accounts for 6.9 percent of the coal, 24 percent of the natural gas usage, and 10 percent of the distillate fuel oil consumed. Commercial and governmental uses account for the remaining fuel oil, coal, and natural gas. These relationships are shown in Figure 12.

Process Emissions

Industrial processes emit 26,000 tons of particulate and 3,400 tons of SO_x in the study area. Ninety-six percent of these pollutants from industrial process losses come from manufacturing plants located in Ohio and Kentucky. The particulate from process losses is primarily mineral dust from Portland cement plants, and metallurgical fume and organic and inorganic dusts from steel, coke, and chemical plants.

Table 19. FUEL BALANCE IN STUDY AREA DURING 1965

Source category	Emission zones										Area total
	Ohio		Kentucky			West Virginia					
	0-1	0-2	K-1	K-2	K-3	W Va-1	W Va-2	W Va-3			
Industrial fuel											
Coal, tons	538,000	32,000	102,000	86,000	45,000	40,000	1,000	3,000	847,000		
Dist. oil, 1000 gal.	6,400	200	31	240	410	190	430	1,190	9,091		
Resid. oil, 1000 gal.	420	710	33	5,340	440	55	120	340	7,458		
Natural gas, 10 ⁶ cf	12,400	5,300	5,500	10,600	220	280	320	1,200	35,820		
Coke oven gas, 10 ⁶ cf	180	7,680	5,370	-	7,280	-	-	-	20,510		
Fuel gas, 10 ⁶ cf	-	-	-	10,000	-	-	-	-	10,000		
Coke breeze, tons	-	3,330	-	26,100	-	-	-	-	29,430		
Commercial and government fuel											
Coal, tons	2,430	2,970	Neg.	3,600	Neg.	Neg.	Neg.	2,250	11,250		
Dist. oil, 1000 gal.	780	950	520	580	1,310	230	180	1,720	6,270		
Resid. oil, 1000 gal.	28	35	9	10	22	55	42	420	621		
Natural gas, 10 ⁶ cf	140	240	150	84	560	1,650	200	1,650	4,674		
Residential fuel											
Coal, tons	26,100	2,400	130	9,480	120	3,180	19,200	3,180	63,790		
Dist. oil, 1000 gal.	970	100	122	80	120	80	15	150	1,637		
Resid. oil, 1000 gal.	-	-	-	-	-	-	-	-	-		
Natural gas, 10 ⁶ cf	680	740	620	510	1,420	3,920	820	3,920	12,630		
Total fuel consumption											
Coal, tons	566,530	37,370	102,130	99,080	45,120	43,180	20,200	8,430	922,040		
Dist. oil, 1000 gal.	8,150	1,250	673	900	1,840	500	625	3,060	16,998		
Resid. oil, 1000 gal.	448	745	42	5,350	462	110	162	760	8,079		
Natural gas, 10 ⁶ cf	13,220	6,280	6,270	11,194	2,200	5,850	1,340	6,770	53,124		
Coke oven gas, 10 ⁶ cf	180	7,680	5,370	-	7,280	-	-	-	20,510		
Fuel gas, 10 ⁶ cf	-	-	-	10,000	-	-	-	-	10,000		
Coke breeze, tons	-	3,330	-	26,100	-	-	-	-	29,430		

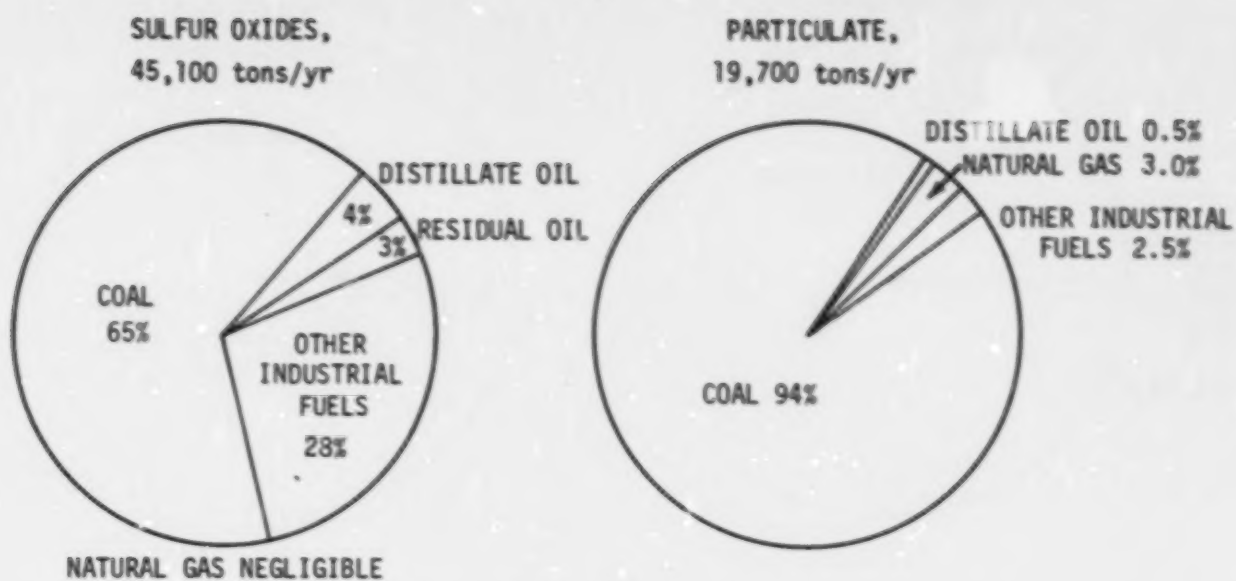


Figure 10. Sulfur oxides and particulate emissions in the study area due to fuel combustion by various fuels

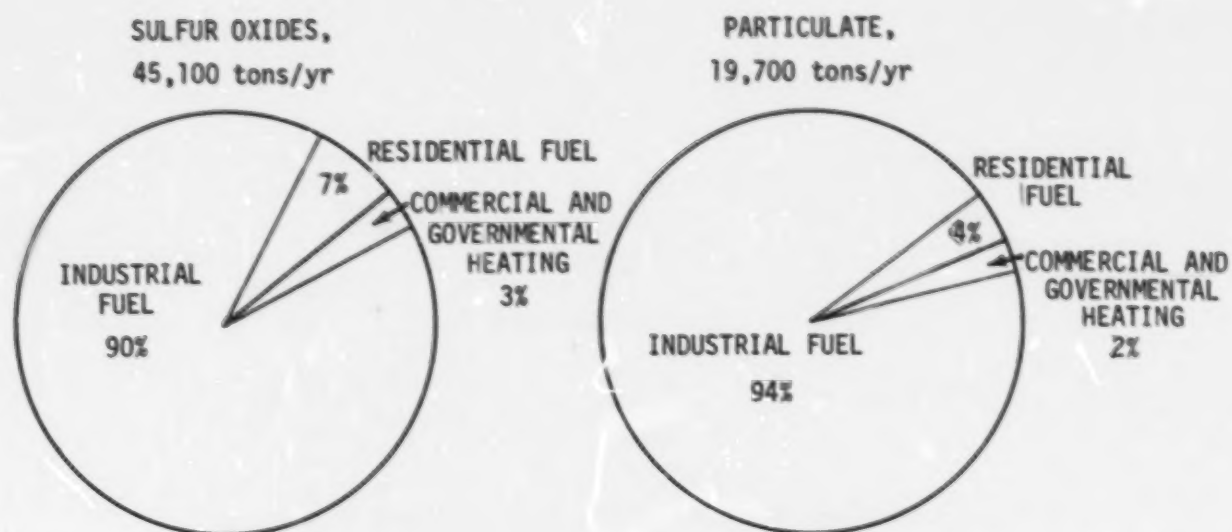


Figure 11. Sulfur oxides and particulate emissions in the study area due to fuel combustion by various sources

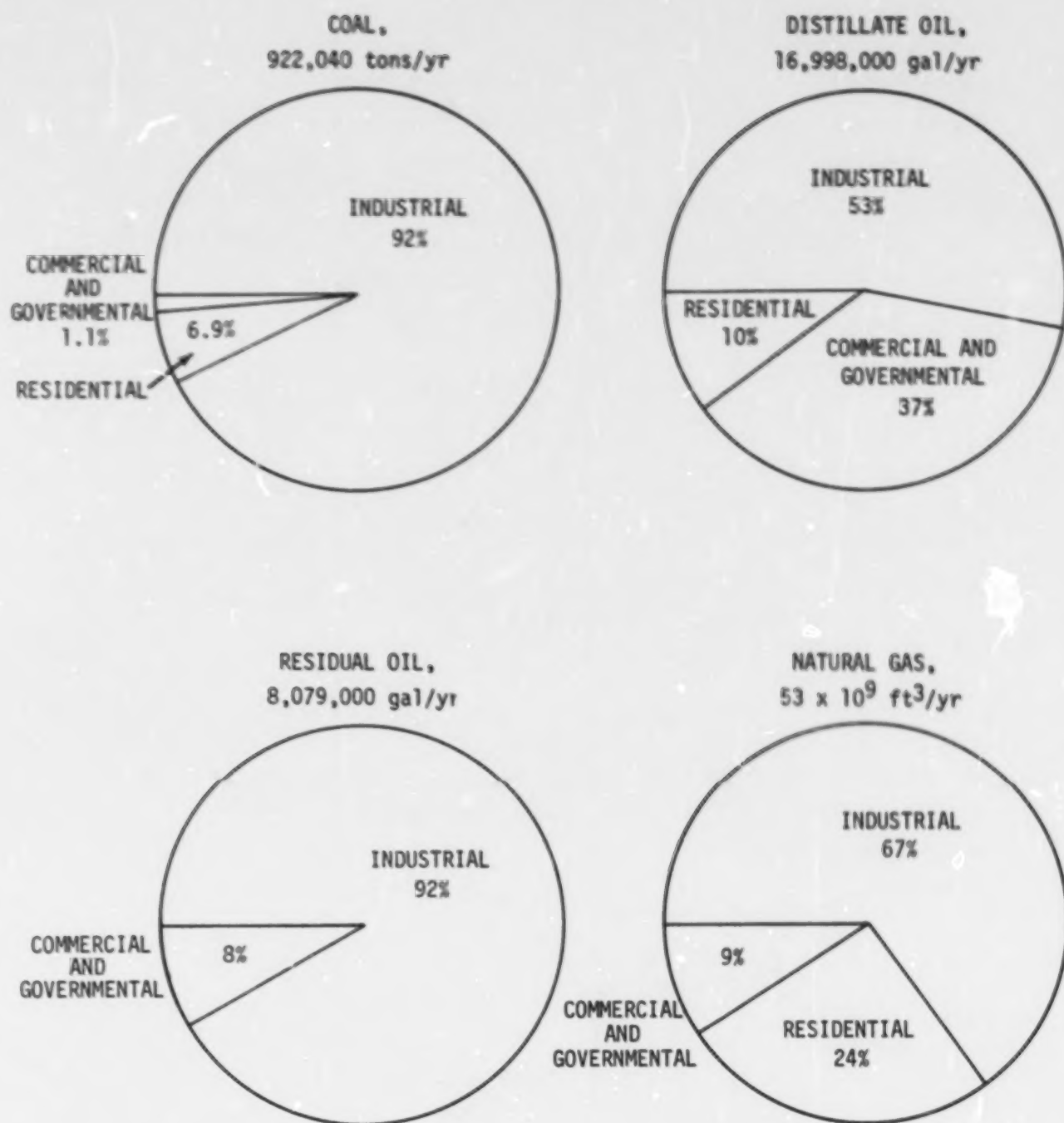


Figure 12. Percentage of each heating fuel consumed in area by various use categories

Refuse Disposal Emissions

Over the course of a year 233,000 tons of refuse is generated in the study area, of which 68 percent is burned in municipal dumps, or by on-site burning by industries and individuals. The remaining 32 percent is either non-combustible refuse or is disposed of in land-fills. Municipal collection service varies from very little pickup in rural areas to almost 97 percent in one urban area. On-site burning in residential and commercial areas and at industrial sites accounts for 70 percent of the combustible material burned; the remaining 30 percent is burned in municipal dumps. A breakdown of refuse disposal data by emission zones is shown in Table 20. The 3,000 tons of particulates from refuse burning amounts to 6 percent of the total area particulate emissions. Only 70 tons of SO_x , a negligible portion of the areas total SO_x emissions, comes from refuse burning.

Table 20. REFUSE DISPOSAL IN STUDY AREA DURING 1965
(tons/year)

Zone	Population	Total refuse produced ^a	Municipal collection ^a	Industrial on site ^a disposal	Amount burned	Emissions	
						Particulate	SO_x
O-1	39,693	32,600			25,300	460	11
O-2	15,745	12,900	2,290	180	10,000	240	6
Ohio						700	17
K-1	29,238	24,000			18,600	320	8
K-2	20,880	17,100		4,170	17,400	320	14
K-3	31,283	25,700	21,400	4,270	9,610	230	6
Ky.						870	28
W Va-1	30,614	25,100			19,500	330	8
W Va-2	32,938	27,000			21,000	350	9
W Va-3	83,627	68,600	66,500	2,060	37,400	880	14
W. Va.						1,560	31
Area totals	284,018	233,000	90,190	10,680	158,810	3,130	76

^aNoncombustible material included in table.

Mobile Sources

Automobiles, buses, and trucks operating in the study area consumed over 90.6 million gallons of gasoline and 6.8 million gallons of diesel fuel during 1965. Together, the burning of these two fuels accounted for 1 percent of the SO_x and particulate emissions in the area. The consumption of gasoline and diesel fuel and the emissions from these fuels are shown in Table 21 for each zone.

Emissions from aircraft, railroad engines, and river traffic were not considered separately in this study since these forms of traffic in the area were not heavy enough to be of significance.

Table 21. MOTOR VEHICLE FUEL CONSUMPTION AND POLLUTANT EMISSIONS

Zone	Fuel consumption, gal		Pollutant emissions, tons/yr	
	Gasoline	Diesel fuel	Particulates	Sulfur oxides
O-1	13,579,000	1,030,000	130	82
O-2	8,704,000	660,000	84	52
Ohio total	22,283,000	1,690,000	214	134
K-1	9,157,000	511,000	79	51
K-2	4,105,000	229,000	35	23
K-3	16,103,000	898,000	140	90
Kentucky total	29,365,000	1,638,000	254	164
W Va-1	6,273,000	564,000	66	40
W Va-2	8,592,000	773,000	90	54
W Va-2	24,142,000	2,171,000	250	150
West Virginia total	39,007,000	3,508,000	406	244
Area total	90,655,000	6,836,000	874	542

Power Plants

There are no commercial power generation plants within the five-county study area. One power generation plant is located approximately 6 miles north of Louisa, Kentucky, and will be discussed later in this report in the section on Point Sources Outside the Study Area.

Point Sources

Any individual site in the study area that emitted 100 tons or more per year of either SO_x or particulate was considered to be a point source. These sources consisted of chemical companies, fertilizer plants, coke plants, cement plants, foundries, and steel plants. Sixteen such point sources produce 33,000 tons of particulate and 40,000 tons of SO_x per year. Locations of these 16 point sources are shown on Figure 7.

The two major categories of point sources of particulate emissions in the study area are chemical plants (37 percent of the area total) and iron and steel manufacturing plants (33 percent of the area total). Chemical plants are also the major point source of sulfur oxides (49 percent of the area total) along with oil refineries

(25 percent of the area total). Particulate emissions from point sources come from fuel combustion and process emissions in about equal portion. The greatest portion of SO_x from point sources is from fuel combustion.

The information used to calculate emissions from the point sources, listed in Table 22, was obtained through the voluntary response of each individual plant to a questionnaire. With a few exceptions, each industry provided information that was converted into annual emissions by applying emission factors developed by the Public Health Service or by utilizing actual emission rates provided by industry on the inventory questionnaire.

Alpha Portland Cement Company supplied to the Public Health Service, on a voluntary cooperative basis, their best estimate of 1700 tons per year as the quantity of particulate matter emitted from the cement kilns in their Ironton plant. The Public Health Service publication, "Atmospheric Emissions from the Manufacture of Portland Cement," indicates that a dry process rotary kiln will emit approximately 46 pounds of particulates per barrel of cement produced. Based on the production rate provided and the reported collection system efficiency, the resultant emissions to the atmosphere would be 2600 tons of particulates per year. An annual emissions of 2600 tons/year has been used in the remainder of this report for calculations used in determining the impact and area-wide effect of this source. It is recognized that this difference in estimated emissions should be resolved.

As noted in Table 22, estimations of emissions from two plants, Armco Steel Corporation, and U.S.S. Chemicals Company, were made by the Public Health Service. The U.S.S. Chemicals Company returned data on an inventory questionnaire but a company request regarding publication of such data resulted in return of the questionnaire to the company by the Public Health Service. Armco Steel Corporation participated in the initial phases of the survey and cooperated fully in a plant visit made by Public Health Service engineers. This company, however, elected not to complete and return the questionnaire on a voluntary basis. Emissions from these sources are the best engineering estimates possible from existing published data on these facilities. These estimates could be verified or more accurate estimates could be made through access to information requested on the inventory questionnaire.

The Agricultural Division of Allied Chemical Corporation manufactures nitrogen fertilizer at its plant at South Point, Ohio. Emissions from fuel combustion at this plant are listed in Table 22. Data provided by this Company indicate that in addition to those emissions from fuel combustion, the plant emits about 4,400 tons per year of nitrogen oxides and about 2,600 tons per year of ammonia.

Table 22. POINT SOURCE EMISSIONS IN STUDY AREA DURING 1965
(tons/year)

Table 22. POINT SOURCE EMISSIONS IN STUDY AREA DURING 1965
(tons/year)

Industry	Fuel combustion		Process emissions		Refuse disposal		Total emissions	
	Particulate	SO _x	Particulate	SO _x	Particulate	SO _x	Particulate	SO _x
1 - Allied Chemical Corp. Agricultural Div.	10,700	17,400	-	-	4	Neg.	10,704	17,400
2 - U.S.S. Chemicals Div. ^a of U.S. Steel Corp.	400	1,150	-	-	-	-	400	1,150
3 - Alpha Portland ^b Cement Company	5	46	1,700	-	-	-	1,705	46
4 - Dayton Malleable Iron Co. Ironton Malleable Div.	45	70	890	-	-	-	935	70
5 - Allied Chemical Corp. Plastics Division	120	150	-	-	-	-	120	150
6 - Allied Chemical Corp. Semet-Solvay Div.	890	2,280	1,000	1,800	-	-	1,890	4,080
Ohio totals	12,160	21,096	3,590	1,800	4	Neg.	15,754	22,896
7 - Armco Steel Corp. ^a	96	620	7,830	-	Not reported		7,926	620
8 - C & O Railway Co. Plant II	360	150	-	-	6	-	366	150
Plant III	90	170	-	-	-	-	90	170
9 - Kentucky Electric Steel Company	2	Neg.	590	Neg.	2	Neg.	594	Neg.
10 - Pittsburgh Activated Carbon Co.	Neg.	Neg.	350	400	-	-	350	400
11 - Ashland Oil and Refining Co.	1,600	10,400	560	500	100	8	2,260	10,908
12 - Allied Chemical Corp. Semet-Solvay Div.	1,790	3,890	1,340	0 ^c	-	-	3,130	3,890
Kentucky totals	3,938	15,230	10,670	900	108	8	14,716	16,138
13 - Novamont Corp.	1,080	1,020	-	-	Neg.	Neg.	1,080	1,020
14 - International Nickel Co., Inc., Huntington Alloy Products Div.	-	-	150	-	Neg.	Neg.	150	Neg.
15 - H. K. Porter Co., Connors Steel Div.	8	Neg.	1,400	-	-	-	1,408	Neg.
16 - Holland-Suco Color Company	230	800	2	Unknown ^d	Neg.	Neg.	232	800 ^d
West Virginia totals	1,318	1,820	1,552	0	Neg.	Neg.	2,870	1,820
Area totals	17,416	38,146	15,812	2,700	112	8	33,340	40,854

^aInformation on this company was either not reported or was not released for use in this report because of company policy. Estimates of the emissions were made by the engineering staff of NCAPC.

^bEmission data supplied by Alpha Portland Cement Company.

^cDuring 1965 the plant's H₂S emissions were not flared to produce SO₂; therefore, 910 tons of H₂S was discharged that year.

^dThe sulfur oxide emissions from the processes employed at Holland-Suco Color Company are unknown at this time. During a plant visit by PHS personnel, it was noted, however, that strong odors of H₂S and SO₂ were observed.

Other Sources

Sources that emit less than 100 tons of pollutant are included as part of the aggregate total of emissions in each reporting zone. Although these sources do not reach the 100 tons per year criterion for listing as point sources, several cause local nuisance problems.

Small quantities of certain pollutants, because of pollutant characteristics or nearness of residential areas, may substantially affect the surrounding environment.

Southern California Chemical Company in Ironton, Ohio, is a local source of odorous hydrogen sulfide emissions. Emissions from this plant are small and vary according to the batch process used to produce certain chemicals; consequently, emission estimates were not made. Intermittent odors, however, can be of major concern in a neighborhood.

Process emissions of particulates were estimated for the Standard Slag Company in Ashland, Kentucky; however, air-borne dusts resulting from wind action on stone storage piles may contribute more particulate to the atmosphere than the company processing. Wind blown dusts from open coal cars in the area and large coal storage piles in South Ironton also were neglected because realistic estimates of actual loss could not be determined. Nonetheless, such emissions are real and constitute a problem to downwind residents.

Occasional burning of car bodies at the Mansbach Metal Company in Ashland produces only small quantities of particulates on an annual weight basis, but local fallout of coarse sootfall particulates from open burning of organic materials in the salvage operation could appreciably affect the nearby commercial district of Ashland.

Point Sources Outside the Study Core Area

Because of their remote locations and meteorological considerations, emissions from certain sources outside the study core area have only limited impact on the air quality in the area; examples are Marquette Cement Manufacturing Company, located at Pedro, Ohio, and Kentucky Power Company, located at Louisa, Kentucky. Marquette Cement Company emits a calculated 7500 tons of particulates per year, and the Kentucky Power Company emits 6240 tons of SO_x annually. Neither of these emissions has been included in the emissions inventory.

Space Heating

An important reason for delineating sources of fuel burning is to ascertain the seasonal variation in emissions due to space-heating requirements. Most of the residential, commercial, and governmental fuel is burned during the winter for space-heating; smaller quantities are used in other seasons for cooking, air conditioning, and water heating. Small manufacturing establishments utilize a portion of their fuel for space heating. However, larger industries, ordinarily utilize excess process steam or some other form of process heat for their space-heating requirements.

Emissions of SO_x and particulates, based on various space-heating days, are shown in Tables 23 and 24. Variation in SO_x emissions from a minimum to a maximum space-heating day amounts to only 70 tons per day. The reason for this small variation is shown in Figure 13. The amount of heat consumed by industrial sources accounts for 73 percent of the total heat consumption. Since this is predominately process heat, emissions are at a constant rate and, therefore, little variation would occur from a minimum to a maximum space-heating day.

The greatest portion of the particulate emissions is from industrial processes and industrial fuel combustion, which are nearly constant throughout the year. Thus, there is very little variation in particulate emissions throughout the year.

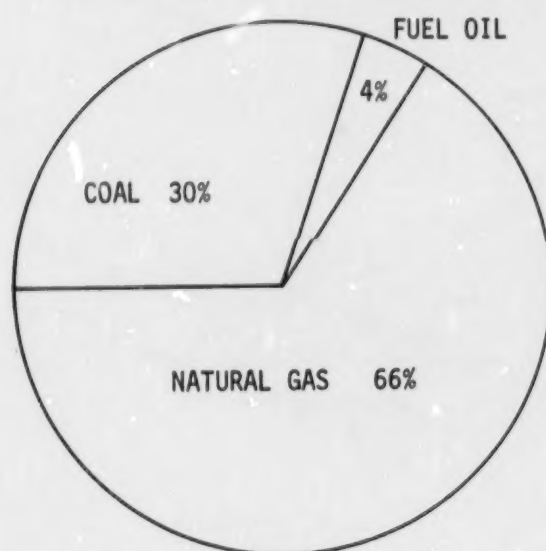
Table 23. SULFUR OXIDE EMISSIONS ON MINIMUM, AVERAGE, AND MAXIMUM SPACE-HEATING DAYS IN THE STUDY AREA DURING 1965

Zone	Area	SO_x emissions, tons/day		
		Min.	Avg.	Max.
O-1	Lawrence County (450 mi ²)	52	59	71
O-2	City of Ironton (6.0 mi ²)	11	14	19
K-1	Greenup County (350 mi ²)	5	5	6
K-2	Boyd County (151 mi ²)	33	36	41
K-3	City of Ashland (8.0 mi ²)	14	21	24
WVa-1	Wayne County (511.6 mi ²)	3	7	12
WVa-2	Cabell County (265.0 mi ²)	1	5	11
WVa-3	City of Huntington (14.0 mi ²)	2	6	13
Totals	Study area 1755.6 mi ²	121	153	197

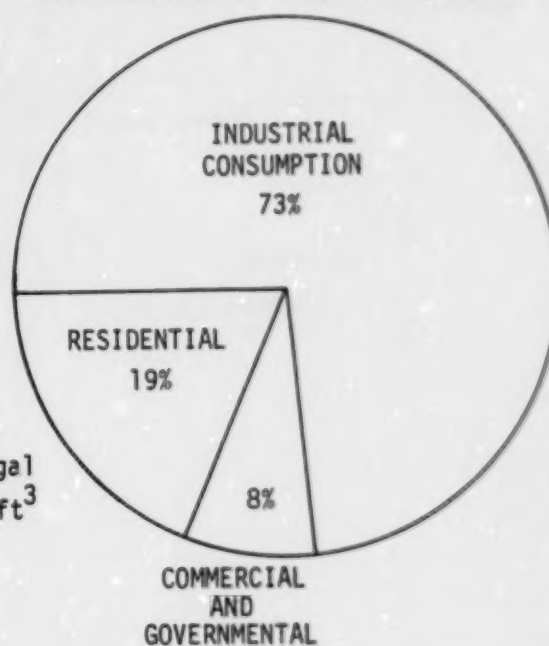
Table 24. PARTICULATE EMISSIONS ON MINIMUM, AVERAGE, AND MAXIMUM SPACE-HEATING DAYS IN THE STUDY AREA DURING 1965

Zone	Area	Particulate emissions, tons/day		
		Min.	Avg.	Max.
O-1	Lawrence County (450 mi ²)	70	72	77
O-2	City of Ironton (6.0 mi ²)	6	7	9
K-1	Greenup County (350 mi ²)	27	27	27
K-2	Boyd County (151 mi ²)	10	12	15
K-3	City of Ashland (8.0 mi ²)	9	9	10
WVa-1	Wayne County (511.6 mi ²)	5	5	7
WVa-2	Cabell County (265.0 mi ²)	2	3	5
WVa-3	City of Huntington (14.0 mi ²)	9	10	11
Totals	Study area 1755.6 mi ²	138	145	161

HEAT SUPPLIED BY PRINCIPAL FUELS



HEAT CONSUMED BY SOURCE CATEGORIES



HEAT VALUES OF FUELS

COAL - 26×10^6 Btu/ton
 FUEL OIL - 142,000 Btu/gal
 NATURAL GAS - 1100 Btu/ft³

Figure 13. Heat consumed by source categories and supplied by principal fuels.

METEOROLOGICAL MEASUREMENTS

Winds

During the course of the survey the Public Health Service operated wind recording systems at Huntington, Kenova, and Ironton. Aerovane wind sensors of the type used at the Tri-State Airport were utilized. The measurements were taken at these valley locations since wind data collected routinely during the study at the Tri-State Airport were not considered representative of the valley conditions. Wind roses for the data collected at the three valley stations are shown in Figure 14.

At the Huntington station, the most frequent wind direction was west-southwest, directly parallel to the centerline of the valley. Winds from this direction occurred 12 percent of the time. South through west winds were more frequent than winds from

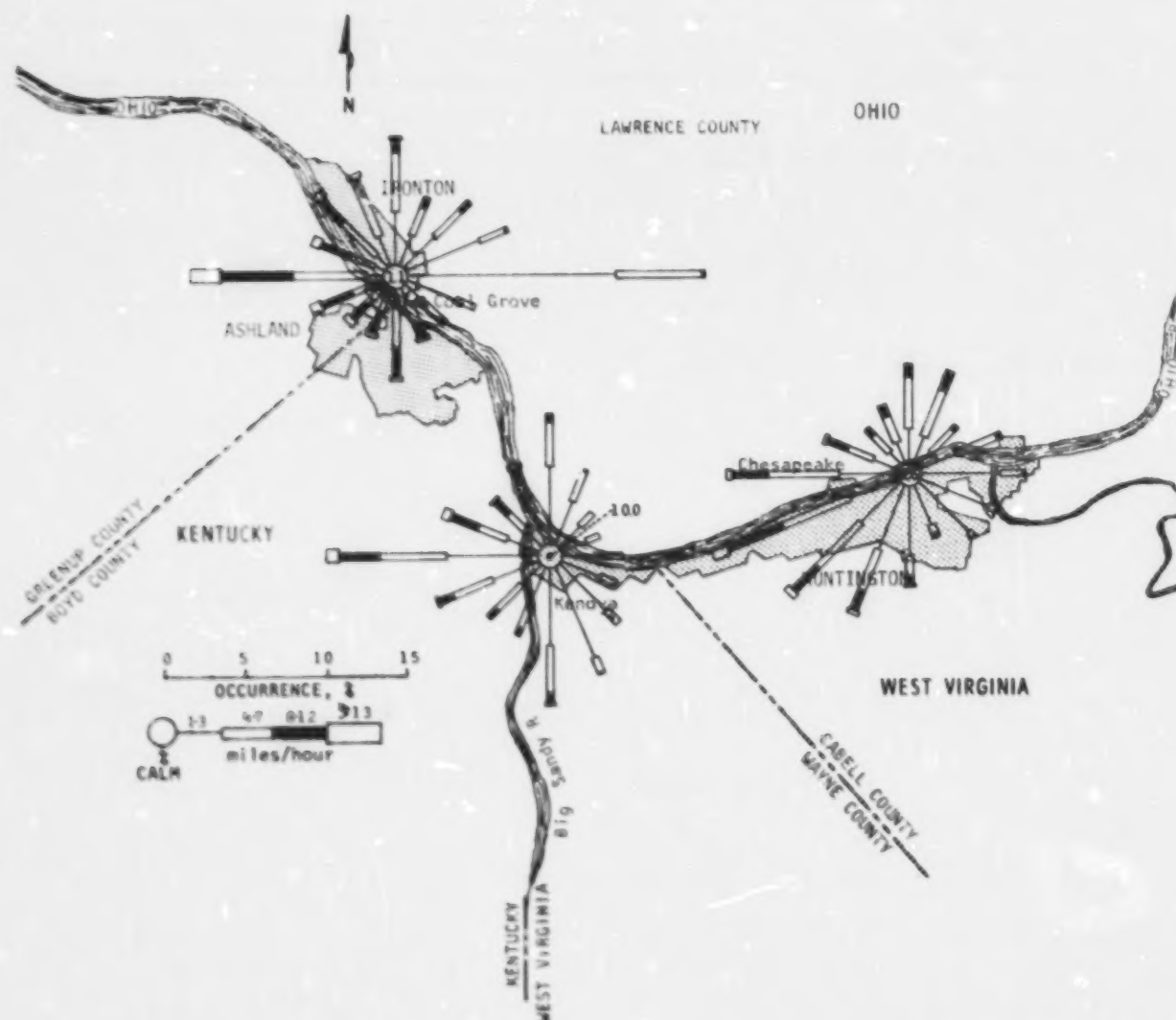


Figure 14. Wind roses for Huntington, Kenova, and South Ironton, September 1965 through August 1966.

other quadrants; this is indicative of the influence of the prevailing winds for the region exclusive of any local topographic effects. The least frequent winds are those that blew across the valley. Northwest, north-northwest, and south-southwest winds each occurred only 3 percent of the time.

The most frequent wind direction at Kenova was west, which occurred 12.8 percent of the time. A westerly flow is generally parallel to the Ohio River Valley at this point. The next two most frequent directions were south and north, indicative of airflow out of and into the Big Sandy River Valley, which is oriented north-south, and which joins the Ohio Valley at Kenova.

The wind rose for the Ironton station also shows the effect of the prevailing winds for the region. The most outstanding feature at the station is the frequent wind from the east, which occurred 18.1 percent of the time. The east wind is caused by nighttime and morning drainage of cold air down the Ice Creek Valley just east of the South Ironton station. The easterly flow is shallow and would not be expected to cross the Ohio River Valley as an east wind. It would join with air in the valley, spread out, or turn and follow the valley, and then augment a northwesterly or southeasterly flow.

Temperature Inversions

As in the case of wind data, vertical temperature information collected at the Tri-State Airport was not considered representative of stability conditions in the valley. To obtain suitable data in the valley, vertical temperature measurements were taken for each of the four seasons using a tethered balloon system in the lower 1000-foot layer above the valley floor. Measurements were made at 2-hour intervals at Kenova, West Virginia, during the periods October 5-10, 1965, May 12-16, 1966, and August 17-25, 1966, and at Ashland, Kentucky, during January 17-22, 1966.

Temperature soundings were made between 4 and 12 a.m. and between 4 and 12 p.m. Useful data were collected in a total of 123 soundings. A summary of the soundings is shown in Table 25. It shows that a temperature inversion condition occurred in 67 of the soundings, and a surface-based inversion in 37 of the soundings. The elevation of the top of the surface-based inversion varied with meteorological conditions, but generally ranged between about 100 and 700 feet. Many of the soundings showed more than one inversion layer, and sometimes inversion conditions existed to the top of the sounding, 800 feet or more above the ground surface. Figure 15 shows examples of surface-based inversions on two successive days. Either would have severely reduced the vertical diffusion of atmospheric pollution.

Table 25. SUMMARY OF TETHERSONDE MEASUREMENTS OF TEMPERATURE INVERSION^a

Time of sounding to nearest hour (E.S.T.)	Seasonal period (1965-66)	No inversion (cases)	Inversion (cases)	Surface-based inversion (cases)	Average top of surface-based inversion (feet)	Inversion aloft with no surface-based inversion (cases)	Average base, lowest inversion layer aloft, no surface inversion (feet)	Average top, lowest inversion layer aloft, no surface inversion (feet)
0400 - 0600	Fall	0	1	1	55	0	---	---
	Winter	0	3	1	110	2	165	565
	Spring	1	4	3	475	1	495	810
	Summer	2	4	0	---	4	95	480
0700 - 0900	Fall	0	3	0	---	3	290	380
	Winter	2	4	1	110	3	365	555
	Spring	8	0	0	---	0	---	---
	Summer	8	4	1	100	3	310	590
1000 - 1200	Fall	0	1	1	210	0	---	---
	Winter	3	0	0	---	0	---	---
	Spring	2	1	0	---	1	930	955
	Summer	7	1	0	---	1	400	595
1600 - 1800	Fall	2	0	0	---	0	---	---
	Winter	1	3	2	165	1	530	645
	Spring	4	3	3	268	0	---	---
	Summer	4	1	0	---	1	805	945
1900 - 2100	Fall	0	2	0	---	2	495	765
	Winter	2	4	2	375	2	535	680
	Spring	2	5	5	300	0	---	---
	Summer	2	9	5	280	4	100	415
2200 - 2400	Fall	0	2	1	100	1	195	470
	Winter	2	1	1	100	0	---	---
	Spring	1	5	5	255	0	---	---
	Summer	3	6	5	380	1	200	595
Total		56	67	37		30		

^aA temperature inversion was considered to have occurred when air temperature increased with height through a layer and the measured temperature increase exceeded 0.5°C.

^bFall - October 5-10, 1965; Kenova, West Virginia

Winter - January 17-22, 1966; Ashland, Kentucky

Spring - May 12-16, 1966; Kenova, West Virginia

Summer - August 17-25, 1966; Kenova, West Virginia

^cDashed line indicates no appropriate data

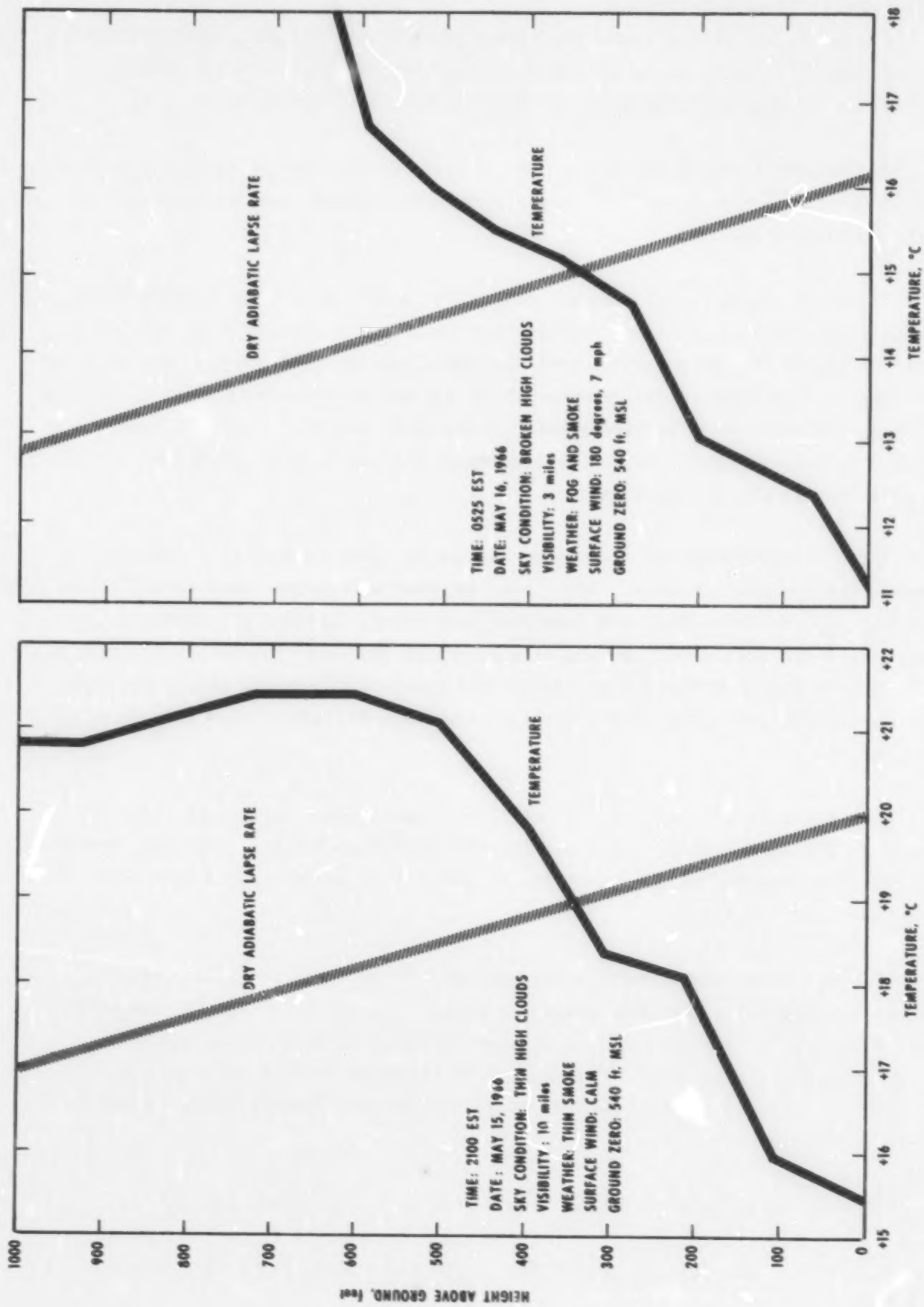


Figure 15. Vertical temperature soundings taken at Kenova, W. Va.

Meteorological Representativeness

In order to properly evaluate the significance of the pollutant data, meteorological data were analyzed to determine whether weather conditions during the sampling period were representative of those normally experienced in the area.

Meteorological data collected at the Tri-State Airport during the study period were compared with the normals^{9,10} experienced over several years at this and previous observational sites.

The entire study period averaged only 1.3°F colder than normal. January and February 1966, however, were much colder than normal. The significance in relation to air pollution is that emissions from the combustion of fuel used for space heating are likely to have been higher than normal during the two mid-winter months. Heating degree-day totals were 34 percent greater than normal in January and 12 percent greater than normal in February. The heating degree-day is used by the fuel industry to estimate fuel use for space heating.

Total precipitation for the period was nearly normal. Monthly precipitation, however, was somewhat variable. April and September were wetter than normal, while December 1965 and March, May, and June 1966 were dryer. Daytime cloudiness was about normal for the overall period, although March 1966 was cloudier than normal, while January and April had comparatively less cloudiness. Precipitation and cloudiness are usually associated with conditions favorable for good atmospheric dispersion of pollutants.

Wind speed is a primary factor affecting dispersion of pollutants since it determines the amount of air available for dilution of pollutants. The mean hourly wind speed for the period was very close to normal, and monthly deviations from normal were not significant.

The pattern of wind direction frequencies for the study period was very similar to that over a previous three-year period (Figure 16.). Notable deviations, about 3 percent in each case, were a greater incidence of south winds and fewer calms during the study period. The greater incidence of south winds indicates that the flow of air pollution from West Virginia and Kentucky into Ohio was somewhat higher than normal.

Some of the monthly departures from normal were significant and may have caused short-term anomalies in the pollutant data collected. Overall, however, the average weather conditions for the period of the study were very nearly normal.

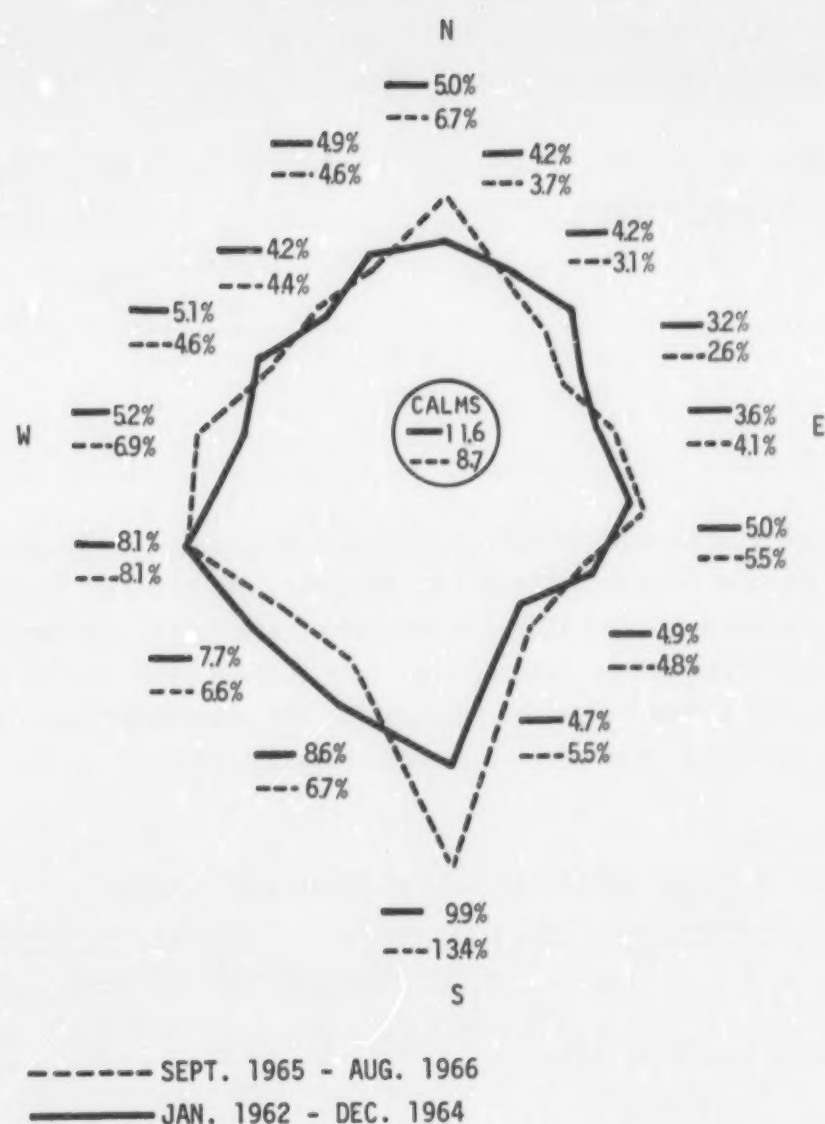


Figure 16. Percent frequency of wind directions for survey period vs comparable long-term period at Tri-State Airport.

MATERIAL EFFECTS MEASUREMENTS

The effects of air pollution on materials are measured throughout the United States at Interstate Surveillance Stations operated by the National Center for Air Pollution Control. In the study area Interstate Surveillance Stations have been operating since January 1966 in Ironton, Ashland, and Huntington. At these three stations measurements were made of zinc and steel corrosion, dye fading, rubber deterioration, silver tarnishing, sulfation, dustfall, and wind-blown particulates. The 1966 and 1967 annual corrosion rates for zinc and steel in the study area are listed in Table 26. For comparison, in 1966, 25 percent of the some 60 Interstate Surveillance Stations had a corrosion rate of less than 0.03 mil penetration

per year (mpy) for zinc and 1.1 mpy for steel; 50 percent of the stations had a rate of less than 0.07 mpy for zinc and 1.4 mpy for steel; and 75 percent of all stations had a rate of less than 0.1 mpy for zinc and 2.0 mpy for steel.

Table 26. ANNUAL CORROSION RATE OF ZINC AND STEEL AT STUDY AREA STATIONS

Stations	Corrosion rate, mpy			
	Zinc		Steel	
	1966	1967	1966	1967
Ironton	0.05	0.05	2.1	1.5
Ashland	0.08	0.04	1.8	1.5
Huntington	0.07	-	1.7	1.5

Dyed fabrics known to be sensitive to oxides of nitrogen and ozone were exposed. The average dye-fading rate in Judd units per 90 days for 1966 and 1967 at the three stations are listed in Table 27. In 1966, 25 percent of all Interstate Surveillance Stations had an average color-change rate of less than 26 Judd units per 90 days for NO_x -sensitive fabric and 17 Judd units per 90 days for the ozone-sensitive fabric. Half of the stations had rates less than 31 and 20, respectively.

Table 27. AVERAGE DYE-FADING RATE AT STUDY AREA STATIONS

Stations	Fading rate, Judd units/90 days			
	NO_x -sensitive		O_3 -sensitive	
	1966	1967	1966	1967
Ironton	23	18	18	15
Ashland	23	15	16	16
Huntington	22	17	18	17

Nylon panels were exposed at three study area sites. Damage to these panels, however, was negligible.

Rubber deterioration was measured during the entire period on a weekly basis; however, because of a sampling discrepancy, all results prior to October 1966 were voided. Figure 17 is a comparison between median and upper quartile cracking rates for all Interstate Surveillance Stations and the average monthly cracking rates for the three stations in the study area. The bars on the graph represent the values not exceeded by 75 percent and 50 percent, respectively, of all Interstate Surveillance Stations, while the individual study area station values are identified by horizontal lines on the figure.

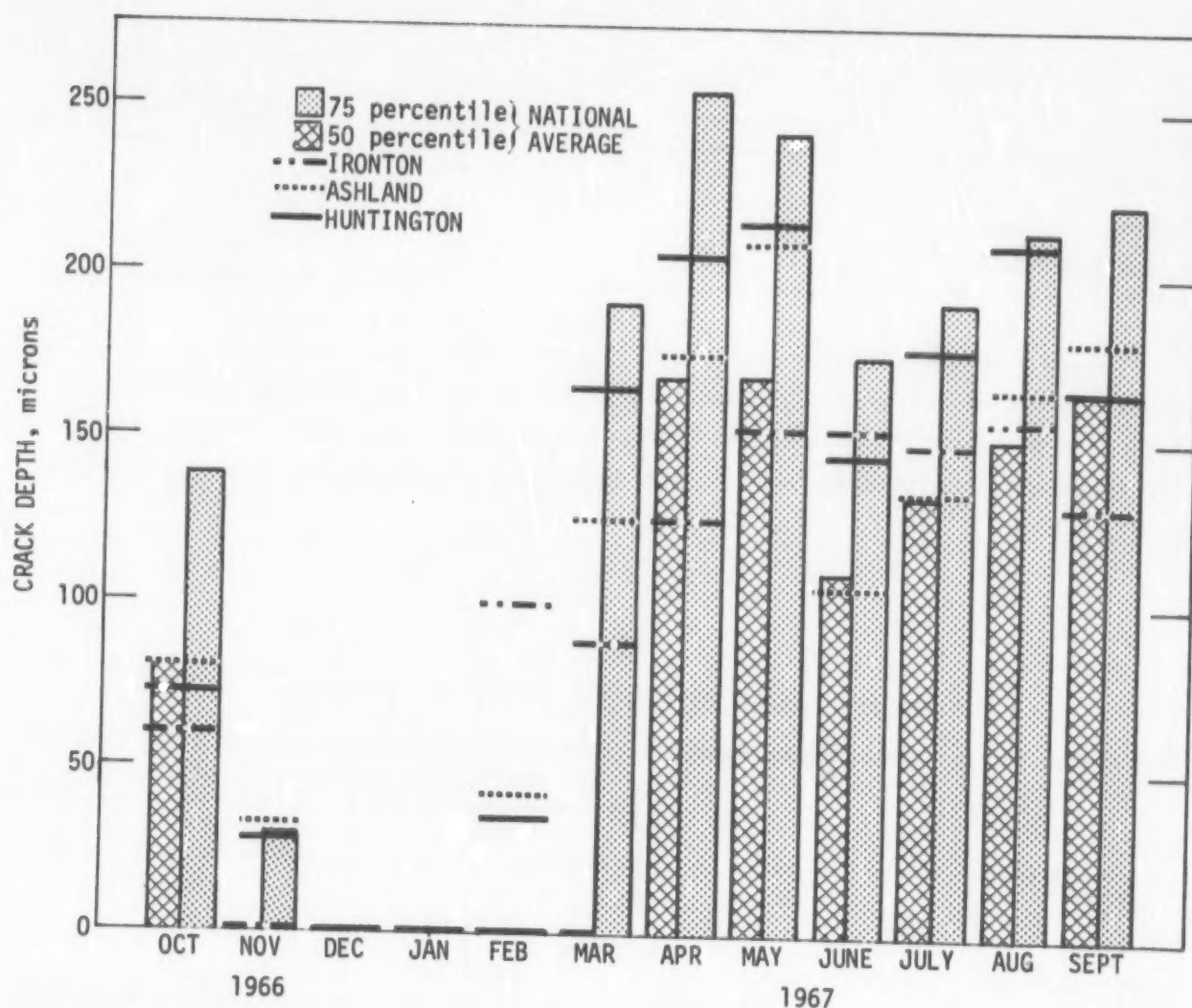


Figure 17. Rubber cracking in study area cities compared with national averages.

In general the rubber cracking at Ironton and Ashland approximates the median levels of the Surveillance Network; however, the levels at Huntington after January 1967 were consistently higher than this median value and often approached the upper quartile levels of the Surveillance Network.

Tarnishing of silver was measured on specimens with 1-month exposure periods. The 1966 and 1967 average tarnishing rates, in percent reflectance loss per 30 days, are presented in Table 28. In 1966, 50 percent of the Interstate Surveillance Stations had a silver tarnishing rate of less than 69 percent reflectance loss per 30 days; 75 percent had a rate of less than 80; and 90 percent had a rate of less than 87.

Table 28. SILVER TARNISHING RATES AT STUDY AREA STATIONS

Stations	Percent reflectance loss per 30 days	
	1966	1967
Ironton	89	88
Ashland	79	73
Huntington	71	71

Annual average sulfation rates are listed in Table 29. The units of sulfation are milligrams of sulfur trioxide equivalent accumulated on 100 square centimeters of surface per day. Results obtained from the effects measurements are consistent with those obtained at sampling stations during the course of the comprehensive air quality survey.

Table 29. SULFATION RATES AT STUDY AREA STATIONS

Stations	Sulfation, mg SO ₃ /100 cm ² -day	
	1966	1967
Ironton	1.0	1.9
Ashland	0.5	0.5
Huntington	0.4	0.3

The annual average dustfall rates listed in Table 30 represent the total dustfall, both soluble and insoluble, and are reported in tons per square mile per month. These data are consistent with those obtained in the comprehensive survey.

Table 30. DUSTFALL RATE AT STUDY AREA STATIONS

Stations	Dustfall, tons/mi ² -mo	
	1966	1967
Ironton	56	59
Ashland	20	17
Huntington	22	17

Wind-blown particulates were measured by a sticky paper method. Vertical cylinders around which are attached bands of adhesive paper with the adhesive surface outward are exposed so wind-borne particles may impinge upon them. Particles are captured and accumulate on the side of the cylinder facing the wind. Results for the three stations are presented in the form of pollution roses in Figure 18. The 1966 and 1967 average deposition rate, reported as the number of particles deposited per square

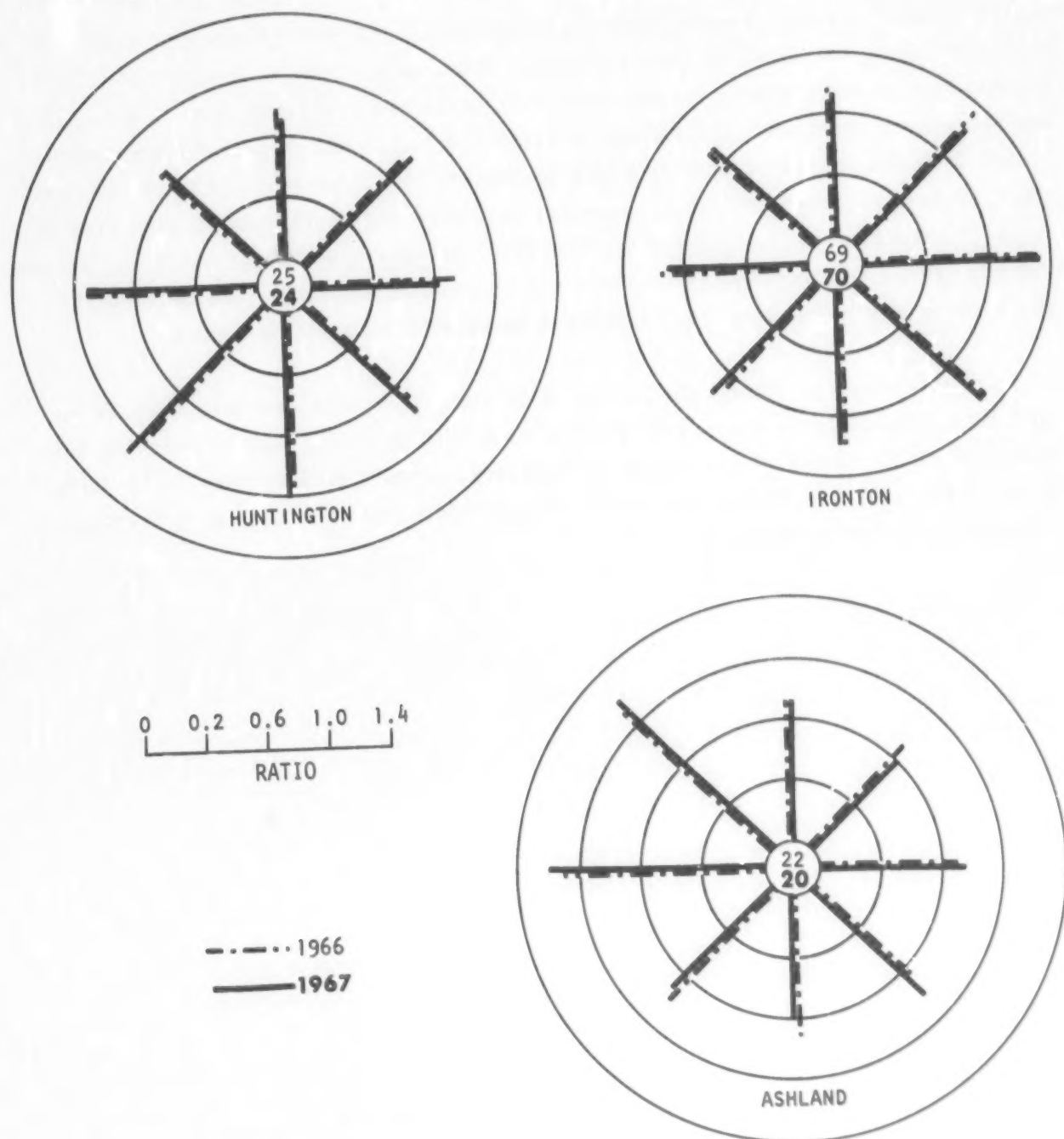


Figure 18. Pollution roses showing ratio of annual rate of particulate loading from each direction to overall annual average rate for all directions, 1966 and 1967.

millimeter of paper exposed for 7 days, is presented in the center of each rose. The lengths of the bars extending from the center are proportional to the ratio of the rate of particle deposition from that direction to the average rate of particle deposition from all directions. The data are presented in this way to show the particulates accumulated when the wind blows from each direction. Since data are available for 2 years, there are two annual averages presented in the center and each direction has two bars. The 1966 average is the upper value and the 1967 average the lower in the center of each figure. From these pollution roses it is readily apparent that 1967 data are almost identical to the 1966 data. The Ironton station receives about 20 percent more particulates from the northeast, east, and southeast than it does from the opposite directions. The Ashland station receives about 40 percent more particulates from the northwest than from the southeast. The Huntington station receives about 30 percent more particulate from the southwest and south than it does from the opposite directions. The Ironton station has extremely high values while the average for the Ashland and Huntington stations are considered moderate. The particulates at all locations were generally classified to be of a combustible nature.

In summary, the Interstate Surveillance Station results indicate that pollution levels have not changed significantly from 1966 to 1967. Rubber cracking indicates that the ozone season starts in February, a month earlier than it is normally expected. The tarnishing of silver, probably from hydrogen sulfide pollution, is a problem in Ironton, Ohio.

V. POLLUTION IMPACT ON STUDY AREA

GEOGRAPHIC DISTRIBUTION OF POLLUTANTS

Iso-intensity maps were constructed for suspended particulate, sulfation, and dustfall results. Mean concentrations of sulfation and dustfall were plotted, and median concentrations were used for suspended particulates. As would be expected, the patterns of pollutant iso-intensity lines coincide with similar high emissions, as determined by the source emission inventory.

The iso-intensity map for suspended particulate high-volume samples appears in Figure 19. The area of highest concentrations, above $125 \mu\text{g}/\text{m}^3$, was centered about the Coal Grove - South Ironton sites. Next highest concentrations, above $100 \mu\text{g}/\text{m}^3$,

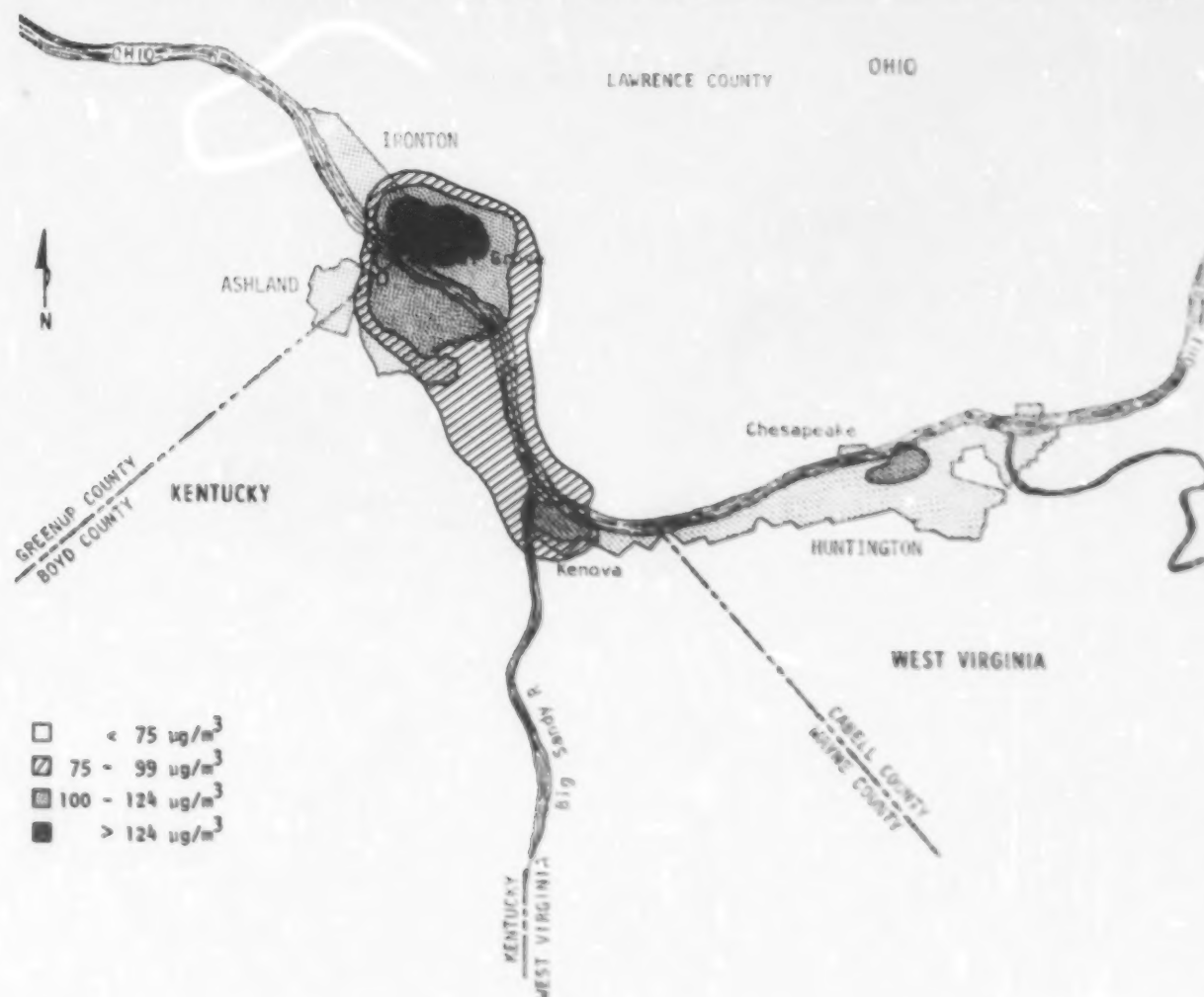


Figure 19. Geographic distribution of median suspended particulate concentrations

form a circular pattern that includes the South Ironton - Coal Grove area and extends south to encompass a large part of the Ashland, Kentucky, area. Two additional areas of suspended particulate in excess of $100 \mu\text{g}/\text{m}^3$ were found in Kenova and Huntington. Concentrations exceeding $75 \mu\text{g}/\text{m}^3$ were generally found to exist over the river valley area extending from the middle of Ironton southeast to Kenova; a similar area exists in Huntington, but its boundary was not defined.

Geographic distribution of settleable particulate (dustfall) is given in Figure 20. Concentrations greater than $25 \text{ tons}/\text{mi}^2 - \text{mo.}$ were found about the South Ironton and Coal Grove sites. Levels in excess of $20 \text{ tons}/\text{mi}^2 - \text{mo.}$ comprise an almost circular area about 4 miles in diameter, centered about the South Ironton station. Other isolated areas of high dustfall levels were found about the Kenova - South Point sites and the central Huntington station. Generally, the entire urban portion of the study area reflected levels in excess of $10 \text{ tons}/\text{mi}^2 - \text{mo.}$

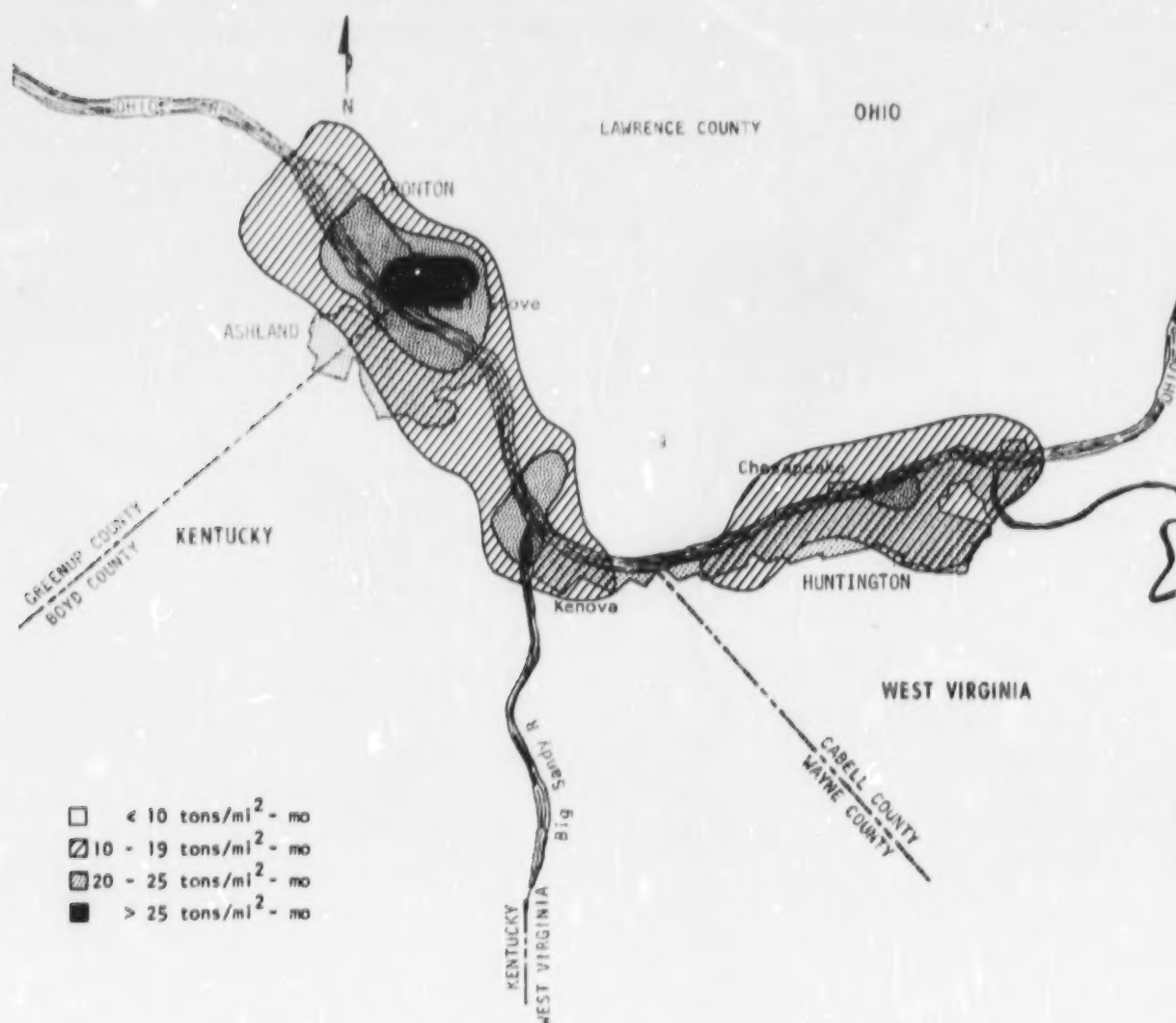


Figure 20. Geographic distribution of mean values for settleable particulate (dustfall).

An iso-concentration map depicting the geographic distribution of sulfation levels is given in Figure 21. Previous studies have shown that these sulfation measurements can be used as a gross indication of sulfur dioxide pollution. As pointed out in earlier sections, existing sulfation data indicate the lack of an overall sulfur dioxide problem in the study area; however, it was considered advisable to present the geographic distribution shown in Figure 21 to pinpoint possible areas where localized problems might occur. The only area depicting sulfation levels in excess of $0.6 \text{ mg SO}_3/100 \text{ cm}^2 - \text{day}$ is centered about the South Ironton - Coal Grove stations.

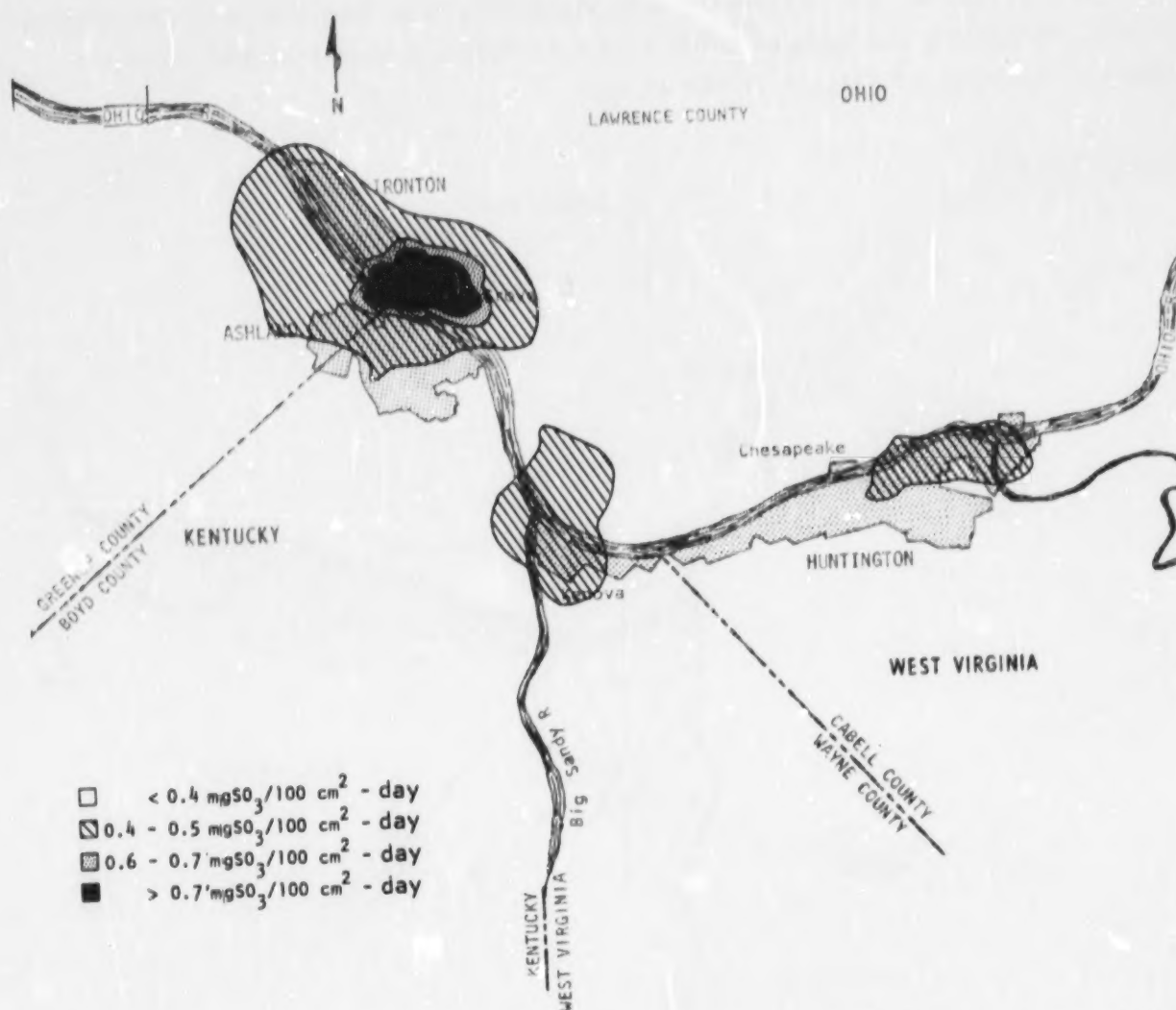


Figure 21. Geographic distribution of mean sulfation concentrations

POLLUTION AND WIND DIRECTION

Smoke

Smoke roses were prepared for the Tri-State Airport to relate the occurrence of smoke, or smoke and haze (in the absence of fog or precipitation) to wind direction. The smoke rose for the period September 1965 through August 1966 is shown in Figure 22. Reduction of visibility by smoke occurred at the airport 7.5 percent of the time. The more prominent smoke directions were northwest through north, constituting about a fourth of the occurrences. In considering only those cases in which visibility was reduced to less than 3 miles, the prominent directions contributed more than a third of 64 hourly occurrences. Instrument navigation is required for flight operations at the airport with visibility less than 3 miles. On three occasions, visibility was reduced below a mile by smoke, a condition that causes severe curtailment of flights at the airport.

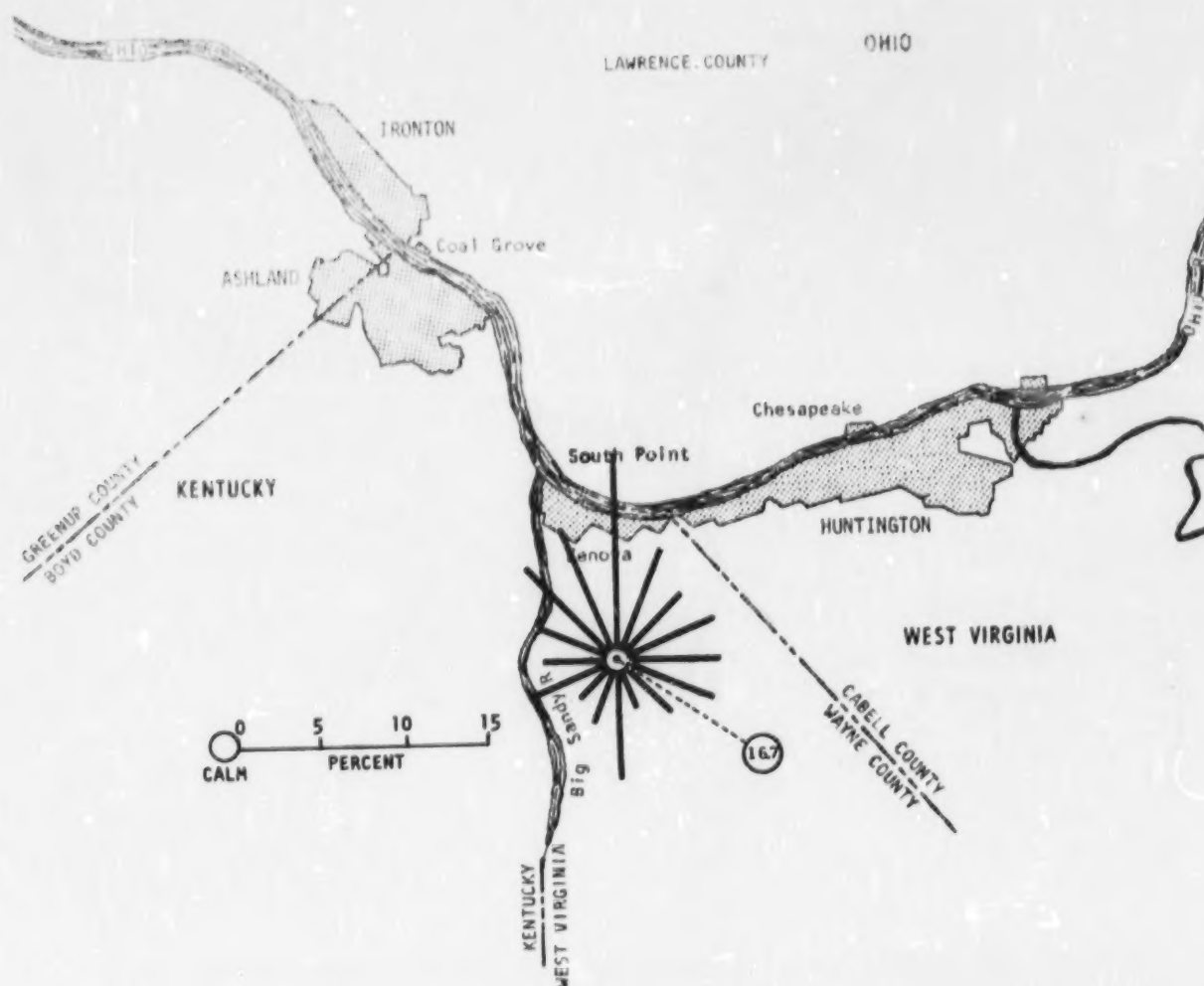


Figure 22. Smoke rose showing percent frequency of wind directions with occurrence of smoke or smoke and haze as a restriction to visibility at Tri-State Airport, W. Va., September 1965 through August 1966.

The smoke roses point to the Ohio River Valley in the direction of major industrial sources in the vicinity of South Point and Ashland as the primary origin of the offending smoke. Interstate transport from Kentucky and Ohio into West Virginia is indicated. Other less prominent legs point to portions of the Big Sandy River Valley and toward the Ohio River Valley in the direction of Huntington as additional sources of smoke. It is evident that smoke pollution causes visibility to be reduced at the Tri-State Airport and occurs frequently enough to significantly affect flight operations.

Soiling Index

Soiling index roses were constructed for the period December 1965 through May 1966. Roses for Ironton, Ashland, and Huntington stations are shown in Figure 23. The roses show the percentage of time each wind direction was accompanied by a Coh value greater than 3.0 per 1000 lineal feet. Data for wind speeds below 1 mph were not included.

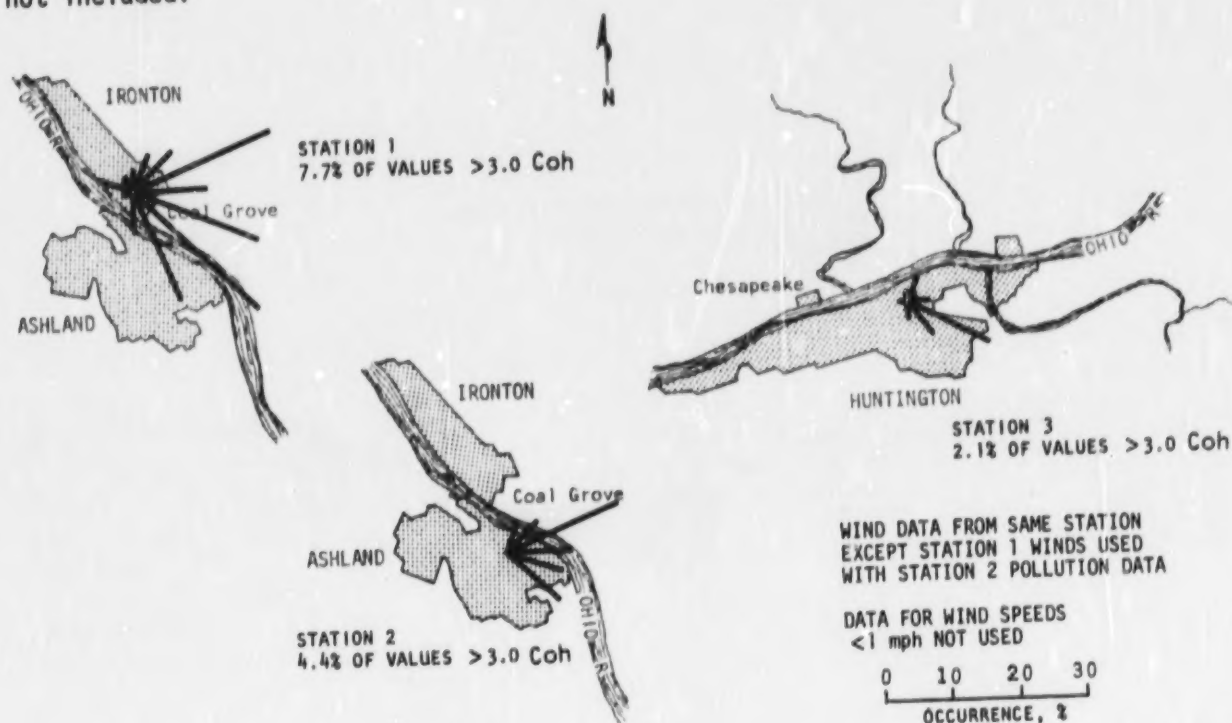


Figure 23. Soiling index pollution roses showing percent of values for each wind direction exceeding 3.0 Cohs/1000 lineal feet, December 1965 through May 1966.

At all stations, winds with an easterly component were frequently accompanied by the higher index values. This in part, reflects relatively lighter winds and less dispersion occurring with easterly flow. At Huntington, the east through

southeast legs are most prominent. Major particulate sources in the indicated directions are Holland-Suco Color Company and Huntington Alloy. The Ashland rose points generally upriver in the direction of the Allied Chemical plants at Ashland and at South Point on the Ohio side of the Ohio River. The rose for the South Ironton station has very prominent legs toward the east-northeast, the direction of Alpha Portland Cement and southeast toward the Allied Chemical (Semet-Solvay) Plant.

Suspended Particulate

Pollution wind roses, Figure 24, were prepared for three sampling stations for the periods when the mean 24-hour concentration of suspended particulates exceeded a given value. At Huntington (3) and Kenova (6) the roses show the frequency of hourly wind directions that correspond to daily concentrations in excess of $200 \mu\text{g}/\text{m}^3$, while at South Ironton (1) the rose relates to values greater than $300 \mu\text{g}/\text{m}^3$. Particulate concentrations were generally higher in South Ironton than at Huntington and Kenova.

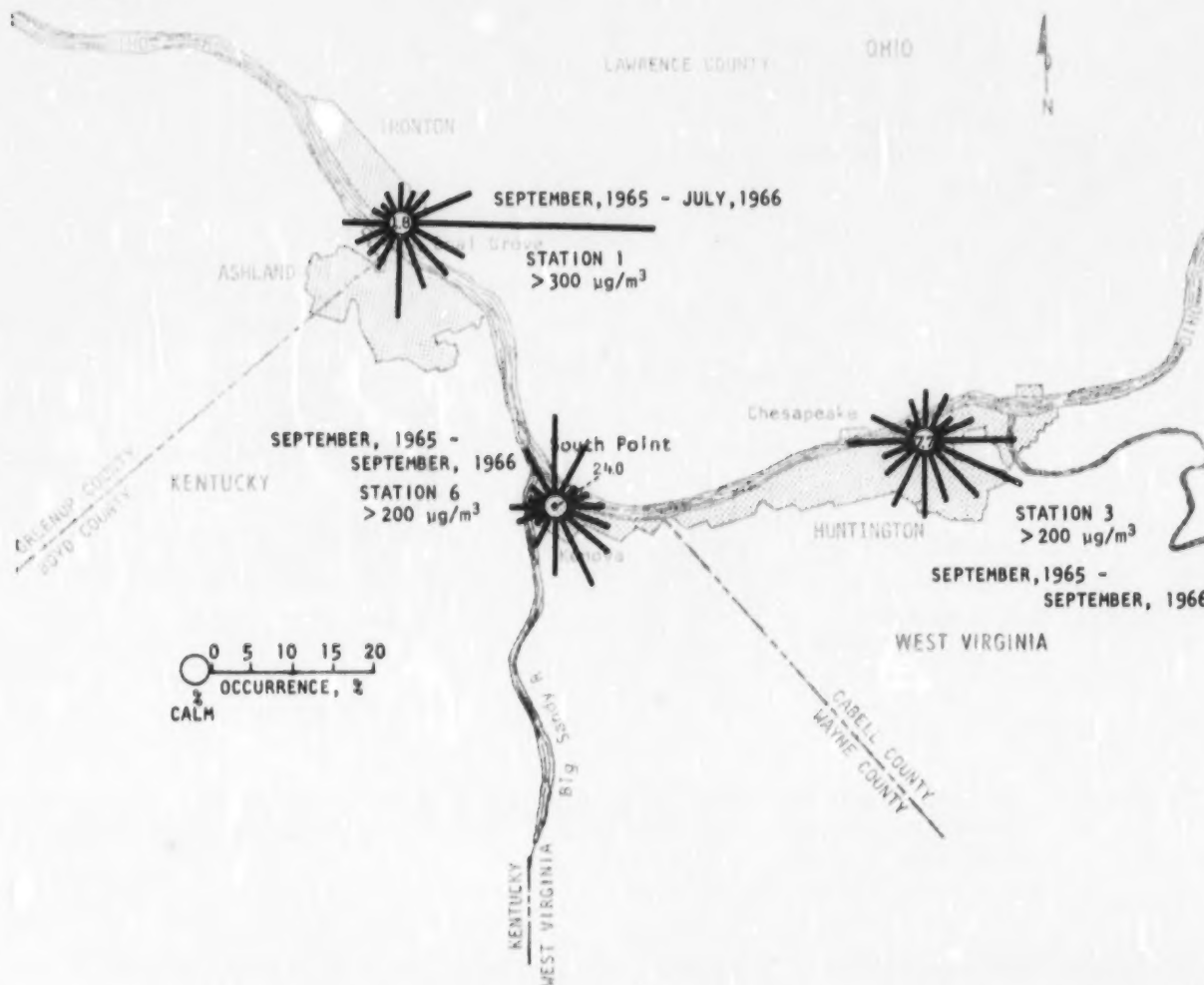


Figure 24. Hourly wind roses for 24-hour periods with suspended particulate concentrations in excess of indicated value.

The Huntington rose shows that east and east-southeast are the most frequent wind directions during high particulate periods. As with the soiling index roses for this station, the east through southeast legs point in the direction of the Holland Suco and Huntington Alloy Plants. The prominent directions at Kenova, north through north-northeast, indicate interstate pollution transport from the Allied Chemical South Point Plant. Also frequent winds with particulate pollution were southeast through south-southeast, the general direction of Huntington with allowance made from the river's bend. At South Ironton east-northeast through south are the frequent directions for high particulate loadings. Such high loadings occurred on about a third of the easterly wind occurrences. Major sources located in the direction of the frequent sector are Alpha Portland Cement to the east-northeast, Allied Chemical (Semet-Solvay) to the southeast, and Allied Chemical Plastics Division and Armco Steel to the south.

Sulfur Dioxide

The concentrations of sulfur dioxide sampled in the area were generally low. Nevertheless, SO_2 pollution roses show a directional influence of higher concentrations of SO_2 sampled. Roses for Huntington, Ashland, and South Ironton are shown in Figure 25. The roses show the percent of time each wind direction was accompanied by an SO_2 concentration exceeding 0.02 ppm.

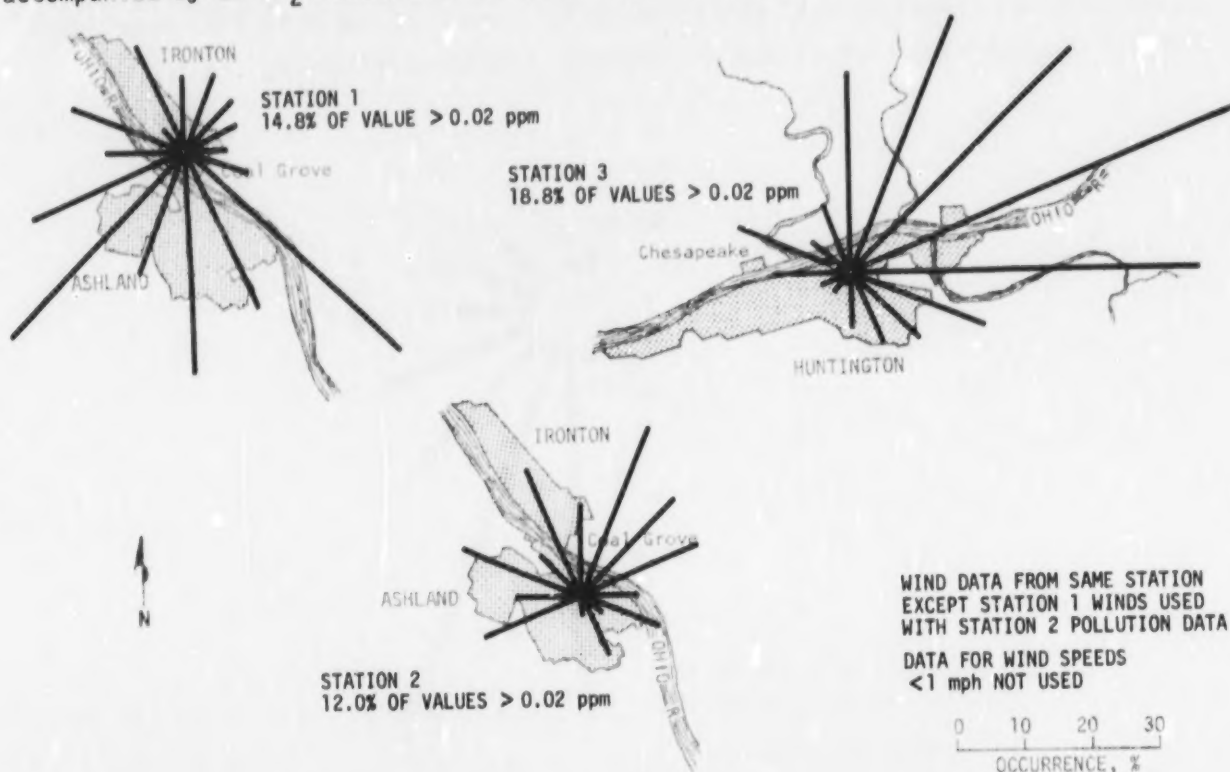


Figure 25. Sulfur dioxide pollution roses showing percent of 2-hour concentrations for each wind direction exceeding 0.02 ppm, September 1965 through January 1966.

At the Huntington station, north through east winds occurred frequently with the higher SO_2 concentrations. Holland-Suco is the only major SO_2 source located in the indicated sector. Sulfur dioxide pollution at Ashland occurred generally with winds from the west-southwest through east-northeast, suggesting transport from sources located in the northwest portion of Ashland and South Ironton. Sulfur dioxide pollution at South Ironton originates from the southeast through west-southwest of South Ironton. Major SO_2 sources in the specified directions that can affect the South Ironton station are Allied Chemical (Semet-Solvay) to the southeast, Allied Chemical Plastics Division to the south, and Armco Steel toward the southwest.

Hydrogen Sulfide

A hydrogen sulfide pollution rose was prepared for two periods during which significant concentrations of hydrogen sulfide were sampled at station 1 in South Ironton. This rose, for the periods December 15, 1965 to January 20, 1966 and April 18, 1966 to May 19, 1966, is shown in Figure 26.

The rose shows frequent occurrence of high H_2S levels with generally southeasterly winds. The most frequent occurrence, 56 percent of the time, was with south-southeast winds. The probable source of the hydrogen sulfide pollution is the Allied Chemical (Semet-Solvay) coking operation, which is known to emit substantial quantities of this malodorous sulfur compound into the atmosphere.

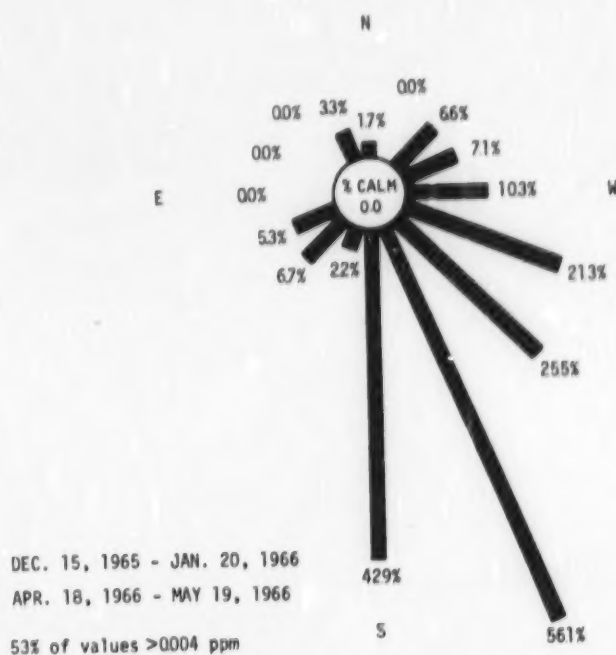


Figure 26. Hydrogen sulfide pollution rose showing percent of 1-hour concentrations for each wind direction exceeding 0.004 ppm, Station 1 - South Ironton.

POTENTIAL IMPACT OF MAJOR POLLUTION SOURCES

Theoretical diffusion calculations were performed to estimate the potential short-term impact of major point sources on selected receptor points. The calculations permit a comparison of the expected to the observed impact indicated by the pollution roses.

Ground-level centerline concentrations of pollutants that can occur at the sampling stations in Huntington, Kenova, Ashland, and Ironton were calculated for each of the significantly contributing sources (Tables 31 and 32). The Gaussian diffusion equation, as given by Gifford¹¹, was used. The calculations give estimates of peak, 3- to 15-minute, concentrations for various stability conditions. Stability was assumed constant in each case through the lowest 1000 meters of the atmosphere. A mean wind speed of 2.0 meters per second (4.5 mph) was used to calculate transport rate for sources emitting within the valley, and 3 meters per second (6.7 mph) was assumed for sources emitting above the valley rim. Calculations for sources emitting within the valley were limited to relatively straight and level portions of the valley to minimize the effect that the valley walls exert on plume dispersion.

The wind roses shown previously in Figure 25 provide indications of the relative frequency that contaminants are transported from the various major sources toward the receptor sites. The directions that the sources lie from the receptors are shown in the tabulations.

The calculations indicate that in the vicinity of Ironton, Armco Steel and Allied Chemical (Semet-Solvay) are potentially two of the larger contributors to air pollution near ground-level. The tabulations for the two Ironton stations show that the South Ironton station should receive higher pollution levels since it is nearer the large sources. The calculations do not consider fallout of larger particulates in the vicinity of the Alpha Cement Plant in South Ironton. About a tenth of the particulate emissions from the Alpha Cement Plant would be expected to fall out near the source. The South Ironton station, located less than a mile from the plant and in the path of frequent easterly winds, would be significantly affected by this fallout.

The two sources that can have the greatest effect on Ashland are Armco Steel and the Allied Chemical Agricultural Division plant at South Point. The Allied Chemical Semet-Solvay plant in South Ashland can also produce a significant contamination at Ashland.

Table 31. CALCULATED GROUND-LEVEL CENTERLINE PARTICULATE CONCENTRATIONS
FROM SINGLE SOURCES UNDER VARIOUS STABILITY CONDITIONS

Station	Source	Direction of source	Distance, km	Concentration ^a , $\mu\text{g}/\text{m}^3$				Stable
				Unstable	Slightly unstable	Neutral	Slightly stable	
8 - Ironton	U.S.S. Chemical Division, U.S. Steel	WNW	13.4	--	--	--	28	59
	Dayton Malleable Iron Company	SSE	2.7	35	104	298	427	449
	Allied Chemical - Semet-Solvay (Ohio)	SE	3.6	28	88	286	493	>1000
	Armco Steel Corporation							
1 - Ironton (south)	-Sintering plant	SSE	3.9	--	39	144	280	587
	-Blast furnace	SSE	3.7	--	27	63	60	--
	-Open hearth	SSE	4.1	195	561	>1000	>1000	488
	-Basic oxygen furnace	SSE	4.4	--	44	--	--	--
	Alpha Portland Cement	ENE	1.1	238	264	24	--	--
	Allied Chemical-Plastics Division	S	0.7	43	109	218	262	197
2 - Ashland	Allied Chemical - Semet-Solvay (Ohio)	SSE	0.4	671	>1000	>1000	>1000	>1000
	Dayton Malleable Iron Company	W	0.6	478	658	249	54	--
	Armco Steel Corporation							
	-Sintering plant	SSW	1.4	136	341	857	>1000	>1000
	-Blast furnace	SW	1.6	78	114	31	--	--
	-Open hearth	SSW	1.4	>1000	>1000	550	52	--
6 - Kenova	-Basic oxygen furnace	S	1.4	43	--	--	--	--
	Allied Chemical-Agricultural Division	SE	6.4	86	276	>1000	>1000	>1000
	Allied Chemical - Semet Solvay (Ohio)	NNW	3.8	25	79	263	457	980
	Dayton Malleable Iron Company	NNW	4.7	--	37	142	250	386
	Armco Steel Corporation	NW	3.8	94	300	944	>1000	>1000
	A. C. Lawrence Leather Company	SE	1.2	21	45	54	28	--
3 - Huntington	Allied Chemical - Semet Solvay (Ky.)	SE	3.4	74	217	555	>1000	>1000
	Allied Chemical - Agricultural Division	N	3.5	226	705	>1000	>1000	>1000
	Ashland Oil	SSW	3.7	40	126	354	419	243
	Allied Chemical - Semet Solvay (Ky.)	NNW	6.5	21	57	179	413	843
	Novamont Corporation	S	11.6	--	--	54	106	171
	International Nickel, Hunt. Alloy	ESE	3.6	--	--	41	80	168
H. K. Porter		NNW	0.5	430	889	>1000	>1000	336
	Holland-Suco Color Company	E	0.7	--	--	--	--	32

^aDashed line indicates concentration of less than 20 $\mu\text{g}/\text{m}^3$.

Table 32. CALCULATED GROUND-LEVEL CENTERLINE SULFUR DIOXIDE CONCENTRATIONS
FROM SINGLE SOURCES UNDER VARIOUS STABILITY CONDITIONS

Station	Source	Direction of source	Distance km	Concentration ^a , ppm			
				Unstable	Slightly Unstable	Neutral	Slightly stable
8 - Ironton	U.S.S. Chemical Division, U.S. Steel Allied Chemical - Semet Solvay (Ohio) Armco Steel Corporation	WNW	13.4	---	---	---	0.03
		SE	3.6	---	0.06	0.12	0.10
		S	3.2	---	---	0.05	0.10
1 - Ironton (south)	Allied Chemical - Semet Solvay (Ohio) Allied Chemical - Plastics Division Armco Steel Corporation	SSE	0.4	0.22	0.09	---	---
		S	0.7	---	0.05	0.10	0.12
		WSW	1.4	0.05	0.12	0.31	0.53
2 - Ashland	Allied Chemical - Agricultural Division Armco Steel Corporation Allied Chemical - Semet Solvay (Ohio) Allied Chemical - Semet Solvay (Ky.)	SE	6.4	0.05	0.16	0.68	1.24
		NW	3.8	---	---	---	0.05
		NNW	3.8	---	0.05	0.12	0.10
		SE	3.4	---	0.08	0.13	0.04
6 - Kenova	Allied Chemical - Agricultural Division Ashland Oil Allied Chemical - Semet Solvay (Ky.) Wood Mosaic	N	3.5	0.13	0.42	1.34	2.05
		SSW	3.7	0.07	0.23	0.64	0.76
		NNW	6.5	---	---	0.06	0.07
		E	0.6	---	0.06	0.11	0.12
3 - Huntington	Holland-Suco Color Company	E	0.7	b	b	b	b

^aDashed line indicates concentration of less than 0.03 ppm.

^bprocess sulfur dioxide emissions not reported.

The main pollution impact at Kenova is indicated to come from the Allied Chemical Agricultural Division plant at South Point. The substantial theoretical impact of SO_2 from the South Point plant is notable since relatively short-term, 2-hour sequential, sampling performed at Huntington, Ashland, and South Ironton appeared to show that SO_2 ground concentration levels in the study area were not excessive. Of the plants along the Big Sandy River, only Ashland Oil appears capable of producing significantly high pollutant concentrations at Kenova.

At Huntington, H. K. Porter, Connors Steel Division, is indicated to be the principal source of particulate pollution. The potential effect of H. K. Porter emissions on the Huntington station is minimized by infrequent winds from the direction of the plant; however, other locations in Huntington in the path of more frequent winds would be affected.

Pollutants other than particulates and SO_2 can also produce significant contamination over portions of the study area. Of particular concern are NO_2 and gaseous ammonia emitted from the Allied Chemical Agricultural Division plant. Theoretical calculations performed to estimate the short-term centerline impact on nearby Kenova showed that NO_2 concentrations of 0.15 ppm can occur under typical daytime conditions (slightly unstable) and 0.85 ppm under typical nighttime conditions (slightly stable). The estimated plume centerline concentrations for gaseous ammonia were 0.24 ppm for daytime and 1.34 ppm for nighttime conditions.

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APPENDICES

Appendix A. ALTIMETER OPERATIONS AND TECHNIQUES

Appendix B. EMISSIONS INVENTORY PROCEDURE

Appendix C. CUMULATIVE FREQUENCY DISTRIBUTION OF POLLUTANTS

Appendix A. AEROMETRY OPERATIONS AND TECHNIQUES

AIR SAMPLING STATIONS

The air sampling network consisted of three major stations located in the principal population centers and 14 minor stations uniformly distributed for area-wide coverage of the study area. The major stations were equipped with various powered air-sampling instruments for several pollutant measurements. The remaining stations were outfitted for fewer measurements; the simplest stations consisted of only static dustfall and sulfation devices.

Table A-1 lists the air sampling stations and types of sampling devices employed at each site.

Table A-1. STATION SUMMARY

Station Number	Name and address	Analyzer	Frequency	Technique
1	State Highway Building 6th St. and Clinton Ironton, Ohio	Particulate Soiling Index SO ₂ -sequential	20/month 12/day 12/day	Hi-vol smoke shade colormetric- West Gaeke
		Effect package H ₂ S Dustfall Sulfation	24/day monthly monthly	PbO ₂ candle
2	Kentucky State Building 19th and Carter Ashland, Kentucky	Particulate Soiling Index SO ₂ -sequential	20/month 12/day 12/day	Hi-vol smoke shade colormetric- West Gaeke
		Effects package Dustfall Sulfation	monthly monthly	PbO ₂ candle
3	Marshall University 5th Ave. and 19th Street Huntington, W. Virginia	Particulate SO ₂ -sequential H ₂ S	20/month 12/day 24 hr/day	Hi-vol colormetric- West Gaeke
		Effects package Dustfall Sulfation	month month	PbO ₂ candle
4	Dawson-Bryant High School Marion Park Coal Grove, Ohio	Particulate Dustfall Sulfation H ₂ S	20/month monthly monthly 24 hr/day	Hi-vol PbO ₂ candle
5	Wade Clay Elem. School 49th and Williams Ashland, Kentucky	Particulate Dustfall Sulfation	20/month month month	Hi-vol PbO ₂ candle

Table A-1. (CONT'D) STATION SUMMARY

Station Number	Name and address	Analyzer	Frequency	Technique
6	American Oil Station Oak and 17th Street Kenova, West Virginia	Particulate Dustfall Sulfation	20/month month month	Hi-vol PbO ₂ candle
7	Burlington Elem. School 3rd Avenue Burlington, Ohio	Particulate Dustfall Sulfation	20/month month month	Hi-vol PbO ₂ candle
8	Briggs-Lawrence Co. Library 321 South 4th Street Ironton, Ohio	Dustfall Sulfation	month month	PbO ₂ candle
9	Poague School 3215 S. 29th Street Ashland, Kentucky	Dustfall Sulfation	month month	PbO ₂ candle
10	Iris Dress Shop 2704 Louisa Catlettsburg, Kentucky	Dustfall Sulfation	month month	PbO ₂ candle
11	Engine Co. No. 8 Camden Street Huntington, W. Virginia	Dustfall Sulfation	month month	PbO ₂ candle
12	Beverly Hills Presbyterian Church Norway and Green Oak Huntington, W. Virginia	Dustfall Sulfation	month month	PbO ₂ candle
13	Chesapeake West Elem. School 3rd Avenue Chesapeake, Ohio	Dustfall Sulfation	month month	PbO ₂ candle
14	First National Bank Ashland Drive Southpoint, Ohio	Dustfall Sulfation	month month	PbO ₂ candle
15	Ironton Junior High School Delaware Avenue Ironton, Ohio	Dustfall Sulfation	month month	PbO ₂ candle
16	Russell High School Stone Road Russell, Kentucky	Dustfall Sulfation	month month	PbO ₂ candle
17	Store Building 2702 First Avenue Huntington, W. Virginia	Dustfall Sulfation	month month	PbO ₂ candle
18	Bellefonte, Kentucky Special sampling site	H ₂ S	24 hr/day	
19	Sheridan, Ohio Special sampling site	H ₂ S	24 hr/day	

SUSPENDED PARTICULATE

High-volume samplers were located in pairs at seven air sampling stations. Each sampler was electrically programmed to operate from midnight to midnight, 24-hours out of every 72 hours; thus, each pair of samplers sampled 2 days of each 3-day period.

Total suspended particulate was collected on 8-by 10-inch glass-fiber filters over 24-hour periods. Results were based on differences between the tare weight and final gross weight of each filter, and volume of air sampled. Data are reported as micrograms of total particulate per cubic meter of air.

SULFUR DIOXIDE

Sequential samplers were used at three stations to collect 2-hour integrated samples of sulfur dioxide. The air stream was passed through bubblers containing West-Gaeke reagent. These samples were then forwarded to the Cincinnati laboratory for colorimetric determination of sulfur dioxide.

LEAD PEROXIDE SULFATION CANDLES

A 17-station sulfation candle network was employed to determine an index of the activity of SO_2 in the study atmosphere. The measurement is based on exposing lead peroxide (PbO_2) paste in ambient air and determining the sulfation caused by gaseous SO_2 . After exposure, the material is stripped from the candles with sodium carbonate, and the amount of sulfate is determined by a turbidimetric procedure. The sulfation rate is reported as milligrams of SO_3 per 100 square centimeters per day. Correlation studies have shown that multiplying this lead candle sulfation value by 0.04 gives as approximation of the average SO_2 concentration in ppm for the period of exposure. This factor when applied under applicable conditions permits gross estimates of SO_2 values.

DUSTFALL

A network of 17 dustfall containers was established to determine the settleable dust rates in the study area. Exposure periods were calendar months. The contents of the containers are rinsed with distilled water and transferred to preweighted beakers. The beakers are placed in a drying oven held at 110°C . The weight of the dry solids is determined, and results are reported in tons per square mile per month.

INTERSTATE SURVEILLANCE STATIONS

Surveillance stations were equipped by the Field Operations Activity of the Abatement Program, Public Health Service, to provide semiquantitative information on types of air pollutants and their effects on specific materials. Three of these stations were operated in the study area.

Table A-2 lists the components of the Interstate Surveillance Stations and the effect demonstrated by each.

Table A-2. SUMMARY OF SURVEILLANCE STATION COMPONENTS AND EFFECTS

Component	Measurement technique	Exposure period, days	Reporting units	Effect demonstration
Steel and zinc panels	Weight loss	365	mil penetration/year, mpy	Corrosion
Silver plate panels	Reflectance	30	Reflectance loss	Tarnishing by H_2S
Cloth fabric dyed panels	Reflectance	90	Judd units	Color change (O_3, NO_2)
Nylon fabric panels	Microscopic examination	30 and 90	Number of breaks/7 in ²	Acidic soot
Rubber panels	Crack depth	7	microns/per 7 days	Material deterioration (O_3)
Dustfall	Gravimetric	30	ton/mi ² -mo	Soiling
Sulfation	Lead peroxide	30	mgSO ₃ /100 cm ² -day	Sulfur dioxide pollution

SOILING INDEX

AISI filter paper tape samplers were installed at two stations. Fine particulate matter was sampled continuously over successive 2-hour intervals, and the darkness of the resulting stain determined by light transmission photometer. Measurements were reported in coefficient of haze (Coh) units per 1000 lineal feet of sampled air.

HYDROGEN SULFIDE

AISI tape samplers with lead-acetate-impregnated filter paper were used at five stations to monitor hydrogen sulfide concentrations. Sampling intervals were of 1-hour duration. Darkening of the paper tape caused by chemical reaction of the tape reagents with hydrogen sulfide was measured by a light transmission technique.

APPENDIX B. EMISSIONS INVENTORY PROCEDURE

A variety of approaches can be used to locate and quantify pollutant emissions in an area, depending on the type of information available. This appendix describes the procedure employed to accomplish this task in the study area. Generally, where emissions were of significant magnitude, efforts were made to obtain exact information, usually by direct interview or mail survey. For the multitude of smaller sources, information was collected from traffic study data, from published information on various sources, and from census figures on population, dwelling units, and manufacturing operations.

The emission survey area included Lawrence County in Ohio, Greenup and Boyd Counties in Kentucky, and Cabell and Wayne Counties in West Virginia. The area was further subdivided into eight reporting zones, as shown in Figure 7. These zones consist of the three major cities and the remainder of the five counties that comprise the study area.

The emissions inventory was initiated in May 1967 to determine the amounts of sulfur oxides and particulates released to the atmosphere over the study area. Data were compiled over a 2-month period. During this period questionnaires were sent to identifiable potential sources of pollution, and visits were made to 14 large industrial establishments. Data were also collected from municipal and private sources in the area to obtain information on traffic, refuse disposal, and fuel usage.

This information was then translated into emissions and reported on an annual basis by source category and by reporting zone. Daily emissions were calculated for minimum, average, and maximum space-heating days to reflect any seasonal variations due to space-heating.

POINT SOURCES

Each source - commercial building, apartment building, industrial plant, etc. - from which 100 tons or more of either sulfur oxides or particulates was emitted per year was considered as a point source. There were 16 such sources in the study area. Most of these sources were visited by Public Health Service personnel to obtain information that would allow calculation of emissions.

MOTOR VEHICLES

The emissions from motor vehicles were subdivided into gasoline-burning vehicles and diesel-oil-burning vehicles. To obtain the quantity of fuel consumed, state consumption totals¹ were apportioned into each reporting zone according to that zone's percent of state service station sales. The inflow of fuel into the area was assumed to be equal to the outflow of fuel for motor vehicles. These quantities of fuel were translated into emissions by applying the appropriate emission factor as listed in Table B-1.

Table B-1. EMISSION FACTORS FOR MOTOR VEHICLES²

Type of fuel	Emission factor, lbs pollutant/1000 gal.	
	Particulates	Sulfur oxides
Gasoline	11	9
Diesel	110	40

Emissions from railroads, airplanes, and river vessels were considered negligible after consideration of the amounts of fuel consumed.

PROCESS SOURCES

The emissions from industrial processes were determined from plant inspections, information obtained from plant officials, and a questionnaire survey. Sources were selected for inspection on the basis of number of employees and type of industry, and from information received from state and local officials. Emission estimates provided by plant officials were compared with reported emissions for plants of similar size and operation. Unless large differences were found, these estimates were used without adjustment. For the most part, the data acquired from plant officials were consistent with emission factors used by the Public Health Service. In those cases in which data were not available, process emissions were estimated by Public Health Service engineers using available references and best engineering judgement.

FUEL COMBUSTION

The sources of fuel combustion emissions were subdivided into (1) residential, (2) industrial and (3) commercial and governmental categories. A fourth category, power generation, is generally included in studies of this type; but this category was excluded since there are no large power utilities in the immediate study area.

The portion of fuel burned for space heating and the portion burned on a constant day-to-day basis throughout the year were determined. Virtually all commercial and governmental fuel, residential fuel, and a small amount of industrial fuel was found

to be consumed for space-heating. The variable use of fuel for space heating determines the difference in emissions on minimum, average, and maximum space-heating days.

Residential Fuel Use

The quantities of fuels consumed in dwelling units were determined from information available on population; dwelling units; and the relative use of coal, oil, and natural gas. The number of occupied dwelling units was obtained from the 1960 Census of Housing.³ These totals were increased in accordance with the percent increase in population for the area, shown in Table B-2.

Table B-2. PERCENT CHANGE IN POPULATION FROM 1960 IN
IRONTON - ASHLAND - HUNTINGTON STUDY AREA ⁴

Area	Population increase, %
Ohio	
Lawrence County	1.3
Kentucky	
Greenup County	4.4
Boyd County	17.5
West Virginia	
Wayne County	0.2
Cabell County	0.7

The amount of fuel required to heat each dwelling unit was applied to these revised totals to obtain the total quantity of each fuel consumed in residential units. It was assumed that the smaller residential units used natural gas, distillate oil, and bituminous or anthracite coal for heating. Bituminous coal was used in Kentucky and West Virginia is all residential coal-burning units. Larger apartment buildings of 50 units or more that used oil or coal were assumed to use residual oil and bituminous coal for all areas.

Coal

The number of occupied units using coal in 1960 was taken from information of the Bureau of Census⁵ and updated to 1965 as described above. It was assumed that no new dwelling units would use coal as a heating fuel; therefore, the number of coal-fired dwelling units in 1965 was assumed to be equal to the units in 1960. It was determined through climatological data that the average coal-burning dwelling unit in the study area requires 6 tons of either bituminous or anthracite coal per year.

The number of dwelling units burning fuel oil was determined in the same manner as was the number of coal users. The 1960 census information was updated to 1965 with the assumption that 20 percent of the new dwelling units use fuel oil as a heating fuel.

The census information reported the number of structures with 50 or more dwelling units. It was assumed that those structures that used oil utilized residual oil as their heating fuel and that all other smaller units consumed distillate oil.

The Ohio portion of the study area had the only significant number of structures with 50 or more dwelling units. The Kentucky and West Virginia portions of the area were assumed to use distillate oil in all oil-burning dwelling units. It was determined from climatological data that each dwelling unit consumes 900 gallons per year of distillate oil or 600 gallons per year of residual oil.

Natural Gas

The quantities of natural gas consumed in the study area were obtained from the gas utilities⁶ servicing each state area. These quantities include natural gas for space heating, water heating, and cooking.

Industrial Fuel Use

Point Sources - Industrial users that were considered to be possible point sources were interviewed or sent questionnaires. The information obtained from these interviews and forms gave the amount of each fuel consumed and its chemical composition. This information was translated into emissions except where the company provided specific emission quantities. These were used in the survey after verification of the calculations.

Homogenous Fuel Use - The amount of fuel consumed in smaller industrial plants, those producing less than 100 tons per year of either sulfur oxides or particulates, was estimated by the following method. The amount of each fuel consumed in industrial plants for each state⁷ was obtained for each reporting zone by using the percent of manufacturing employees⁸ as an indication of industrial activity. The amount of fuel consumed at the point sources in each reporting zone was subtracted from this total, with the remaining fuel representing the consumption of small industrial establishments. This amount was then checked with local fuel dealers and governmental officials and then empirically adjusted to be as accurate as possible. The quantities of natural gas consumed in this category was obtained through the gas utility companies.

Commercial and Governmental Fuel Use

Point Sources- Information was received from Federal, state, and local governmental agencies on an individual basis when data were available.

Homogenous Fuel Use- The homogenous fuel usage for commercial and governmental establishments was determined by proportioning the fuel consumption for commercial and governmental sources into the study area by using the percentage of wholesale and retail establishments to indicate the fuel consumption in this category.

REFUSE DISPOSAL

The amount of refuse disposed of in the study area was acquired through interviews with municipal officials. City and county officials were contacted as to the quantities of refuse collected, the mode of disposal, and any pertinent information regarding private haulers, open burning, etc. It was assumed that, annually each person accounts for 1640 pounds of refuse, of which 1275 pounds is combustible. This amount was applied to the population of each zone to obtain a total amount of refuse generated. The amount of refuse collected by municipal and private services was subtracted from this total, and the remainder represents the amount of refuse disposed of on-site.*

The refuse generated at industrial establishments was obtained by questionnaire. The amount of refuse disposed on on-site was determined, and the amount hauled to off-site disposal areas was allocated to these respective areas. The amount of refuse burned at the municipal dump was estimated, and the appropriate emission factors were applied to each of the categories.

DAILY VARIATIONS IN SULFUR OXIDES AND PARTICULATES RESULTING FROM SPACE HEATING

Emissions for the minimum, average, and maximum space-heating days for 1965 were determined. The emissions of sulfur oxides and particulates were divided into a variable fraction resulting from space heating and a steady fraction resulting from operations that are essentially constant throughout the year.

The space-heating emissions consist of:

1. All commercial and governmental emissions.
2. A portion of industrial fuel combustion emissions.
3. A portion of the residential fuel combustion emissions.

The steady emissions consist of:

1. All process emissions.
2. A portion of the industrial fuel combustion emissions.
3. A portion of residential fuel combustion emissions.

* On-site means the refuse is disposed of on the premises where it is generated.

4. All refuse disposal emissions.

5. All vehicular emissions.

On a minimum day, it was assumed that there was no space heating; therefore, emissions are represented by the above-mentioned steady emissions.

Average and maximum space-heating-day emissions were calculated by adding fractions of the variable emissions to the steady emissions, during respective days. Heating degree-day data acquired from the U. S. Weather Bureau were used to determine those fractions of the yearly variable pollutants that are emitted during average and maximum heating days.

The following formulas were used to calculate the daily emissions.

Minimum day = Steady emissions (tons/day)

Average day = Minimum day + Variable emissions (tons/yr) $\frac{20}{4446}$

Maximum day = Minimum day + Variable emissions (tons/yr) $\frac{53}{4446}$

The fractions (20/4446) and (53/4446) represent the fraction of annual degree-days occurring on the average and maximum heating days.

APPENDIX B. REFERENCES

1. "Analysis of Motor-Fuel Usage in Calendar Year 1965". Tables G-21 and G-25, Department of Commerce, Bureau of Public Roads, July 1966.
2. Mayer, M., "A Compilation of Air Pollution Emission Factors for Combustion Processes, Gasoline Evaporation, and Selected Industrial Processes." Department of Health, Education and Welfare, Public Health Service, Division of Air Pollution, Technical Assistance Branch, Cincinnati, Ohio, May 1965.
3. "Census of Housing 1960". United States Bureau of Census, HC(1)(19)(37)(50), United States Department of Commerce, 1960.
4. "County and City Data Book, 1962". Bureau of Census, Department of Commerce.
5. "Census of Housing, 1960". United States Bureau of Census HC(1)(19),(37)(50) Department of Commerce, 1960.
6. Personal communications, local gas utilities in each state.
7. Minerals Yearbook, Volume 11, 1962 and 1964, Department of Interior, Bureau of Mines.
8. "Census of Manufacturing Area Reports Ohio, Kentucky, West Virginia". Department of Commerce.

Appendix C. CUMULATIVE FREQUENCY DISTRIBUTION OF POLLUTANTS

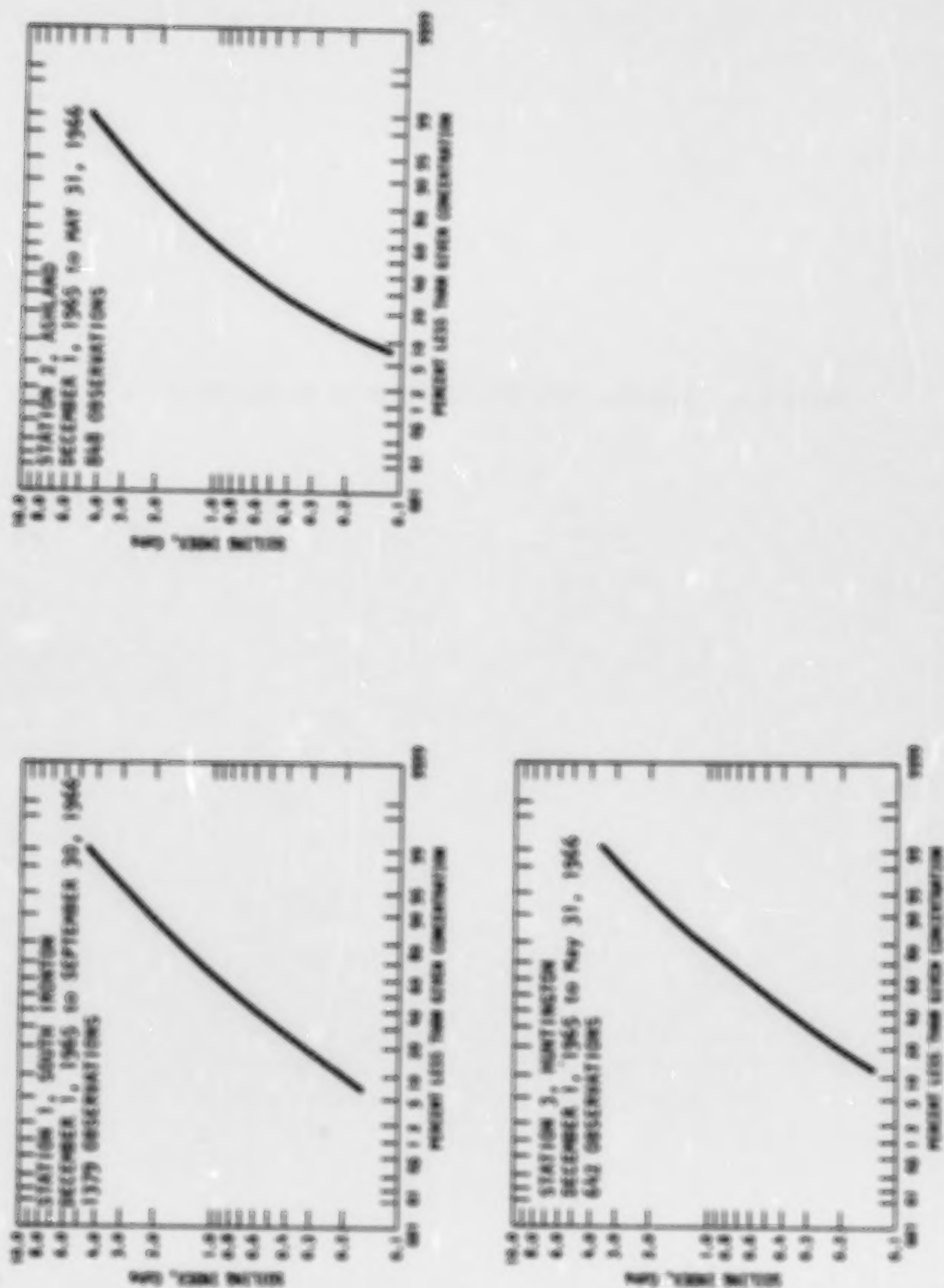


Figure C-1. Selling index 2-hour cumulative frequency distribution for South Ironton, Ashland, and Huntington.

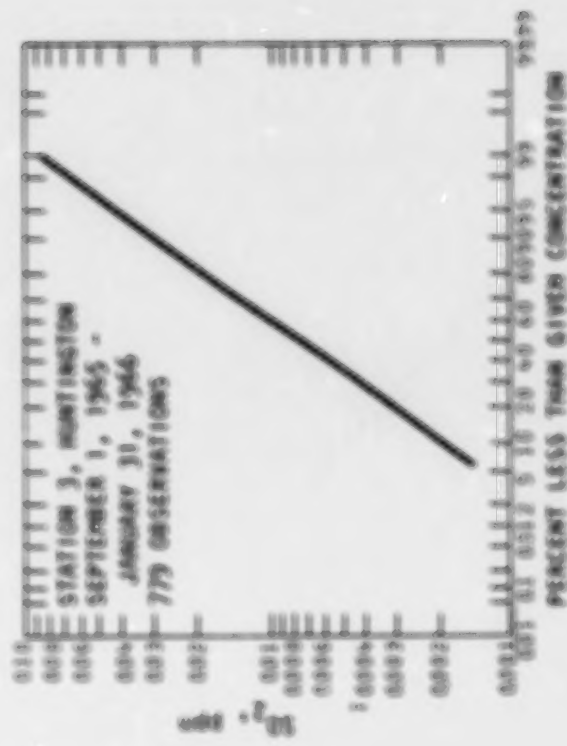
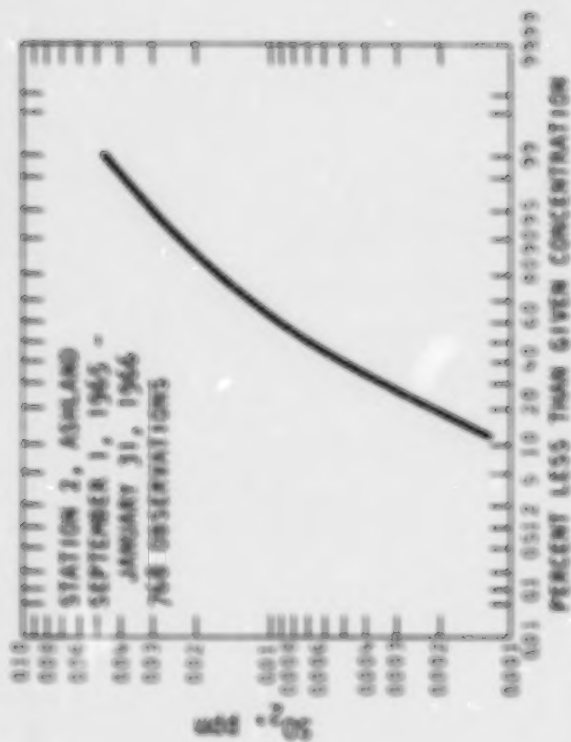
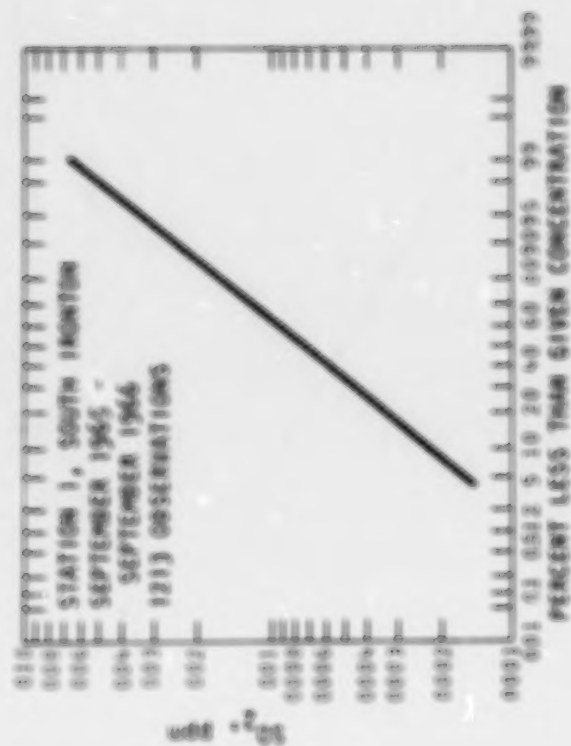


Figure C-2. Sulfur dioxide 2-hour cumulative frequency distribution for South Ironton, Ashland, and Huntington.

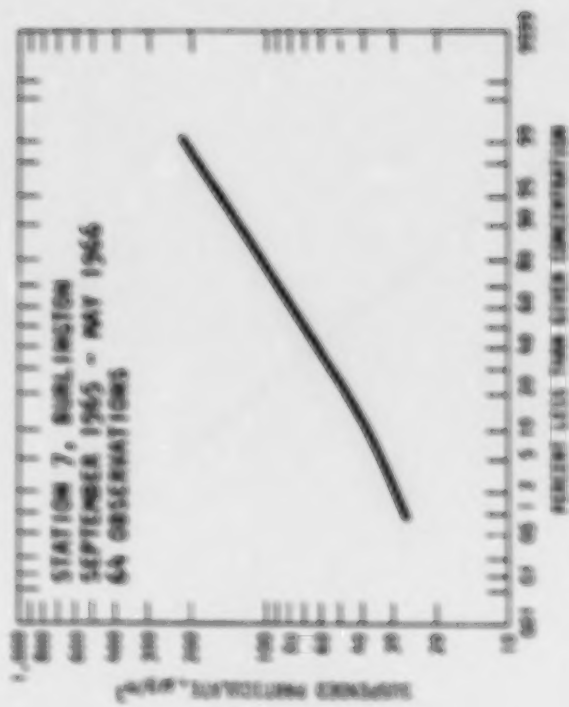
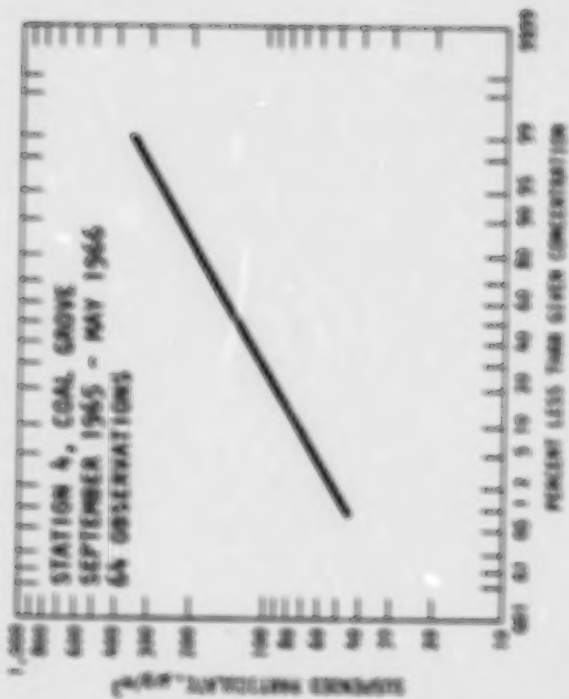
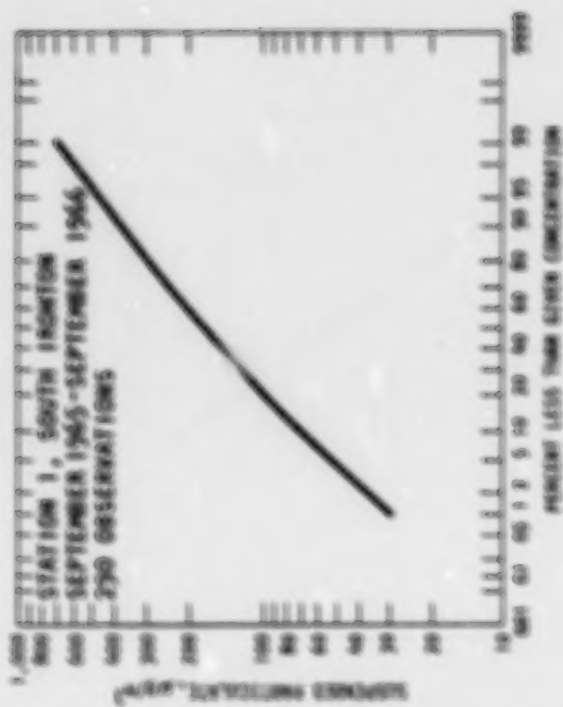


Figure C-3. Suspended particulate cumulative frequency distribution for South Ironton, Coal Grove, and Burlington.

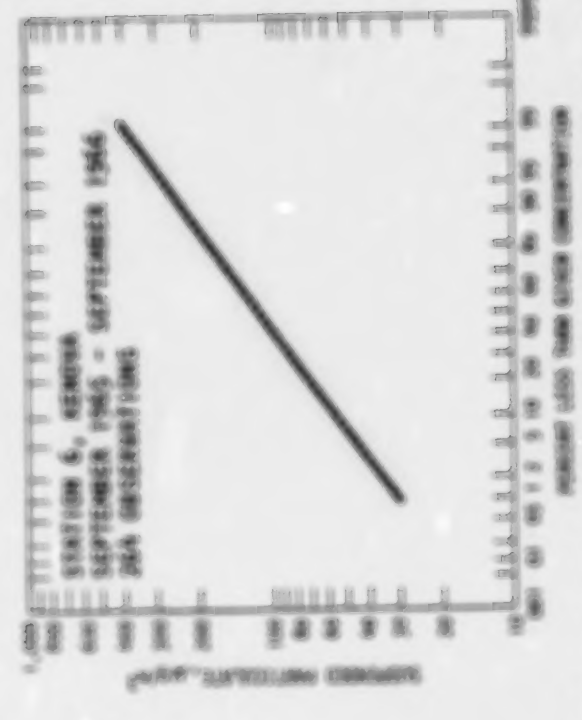
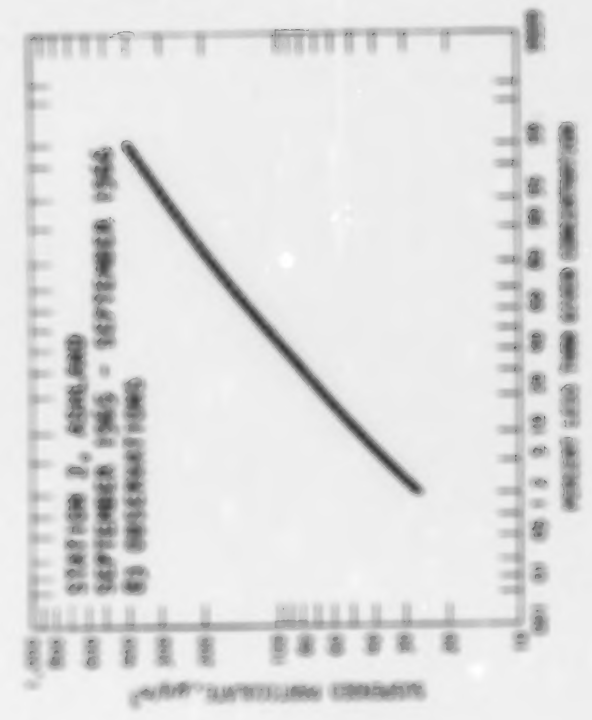
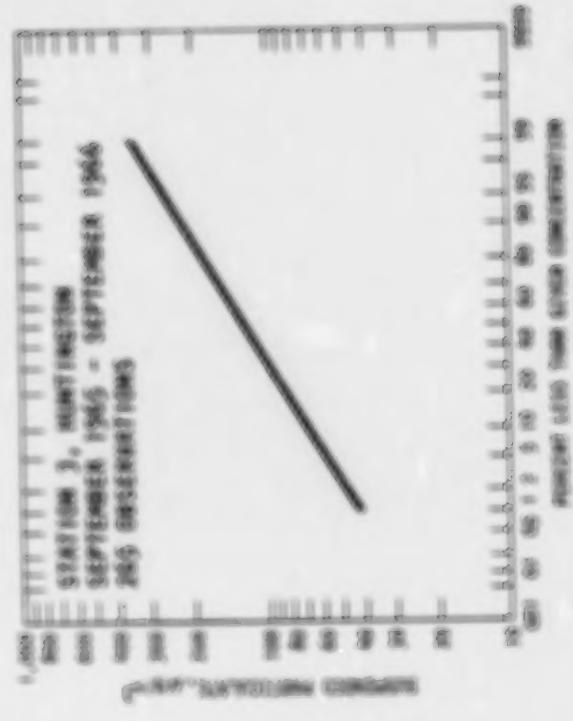
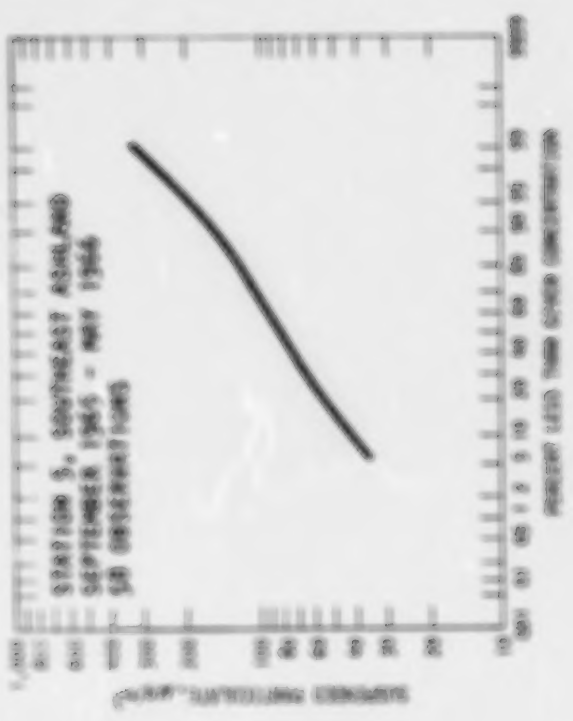


Figure C-4. Suspended particulate cumulative frequency distribution for Ashland, Southeast Ashland, Kenova, and Huntington.

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16. Key Words and Document Analysis (a). Descriptors <table border="0"> <tr> <td>Air pollution</td> <td>Combustion products</td> <td>Metallurgical converters</td> </tr> <tr> <td>Abatement</td> <td>Dust</td> <td>Space heating</td> </tr> <tr> <td>Cements</td> <td>Aerosols</td> <td>Refuse disposal</td> </tr> <tr> <td>Atmospheric corrosion</td> <td>Smoke</td> <td>Ground vehicles</td> </tr> <tr> <td>Cracking (fracturing)</td> <td>Coal</td> <td>Chemical composition</td> </tr> <tr> <td>Fading</td> <td>Fuels</td> <td>Exhaust emissions</td> </tr> <tr> <td>Steels</td> <td>Flammable gases</td> <td>Inventories</td> </tr> <tr> <td>Zinc</td> <td>Fuel oil</td> <td>Mapping</td> </tr> <tr> <td>Elastomers</td> <td>Chemical plants</td> <td>Wind (meteorology)</td> </tr> <tr> <td>Valleys</td> <td>Thermal power plants</td> <td>Temperature inversions</td> </tr> <tr> <td></td> <td></td> <td>Nitrogen oxides</td> </tr> <tr> <td></td> <td></td> <td>Sulfur dioxide</td> </tr> <tr> <td></td> <td></td> <td>Odors</td> </tr> <tr> <td></td> <td></td> <td>Sulfation</td> </tr> <tr> <td></td> <td></td> <td>Environmental surveys</td> </tr> </table>				Air pollution	Combustion products	Metallurgical converters	Abatement	Dust	Space heating	Cements	Aerosols	Refuse disposal	Atmospheric corrosion	Smoke	Ground vehicles	Cracking (fracturing)	Coal	Chemical composition	Fading	Fuels	Exhaust emissions	Steels	Flammable gases	Inventories	Zinc	Fuel oil	Mapping	Elastomers	Chemical plants	Wind (meteorology)	Valleys	Thermal power plants	Temperature inversions			Nitrogen oxides			Sulfur dioxide			Odors			Sulfation			Environmental surveys
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